REFINER
AND NATURAL GASOLINE MANUFACTURER

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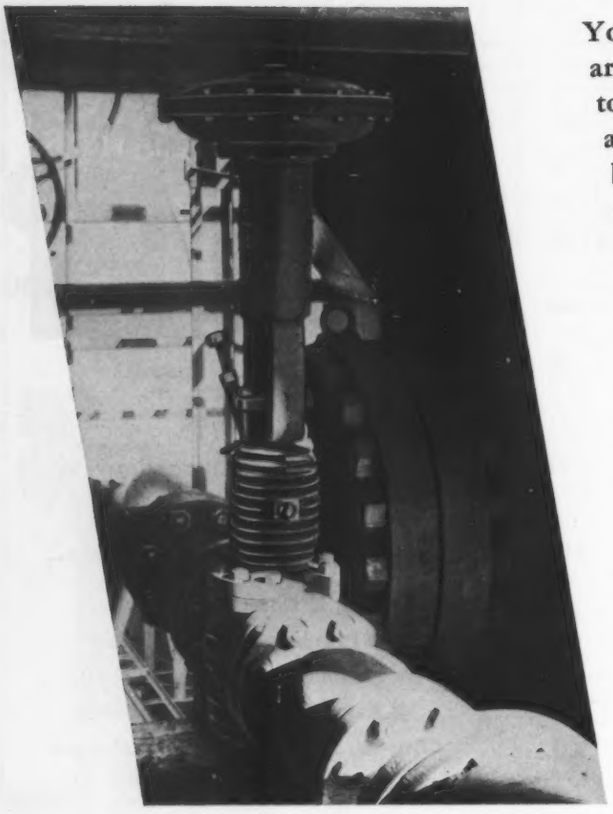
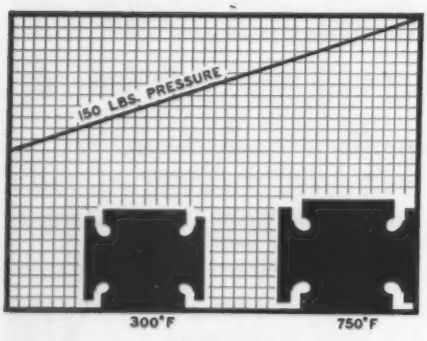
YOU NEED *More Valve* HIGH TEMPERATURE

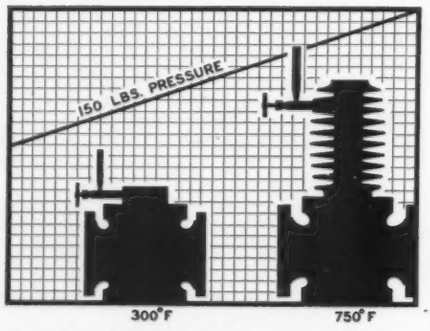


You need *More Valve* when high temperatures are involved—and adding a cooling member to protect the stuffing box is not enough. In addition you need greater strength in the valve body, greater power in the diaphragm motor and springs, and stronger stems to transmit that power.

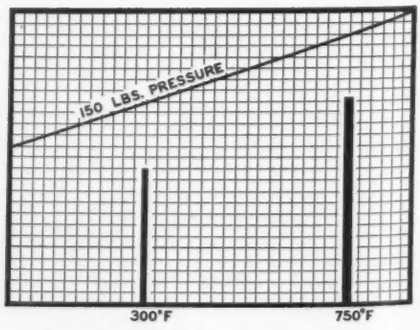
For this reason a Masoneilan high temperature valve is entirely different from a standard valve —it is built *throughout* for high temperature service. The body may have to be heavier. The valve plugs and guides are specially designed; special alloy trim may be required; valve stems are heavier to offset loss of tensile strength at high temperatures; an air-fin bonnet, with a proved efficiency far greater than is usual on other valves, is used to hold stuffing box temperature at approximately 200°F; the diaphragm area is increased at least 33% to



The pressure-temperature conditions may require using a heavier body or a body of different metallic composition.



Changing from standard to air-fin bonnet increases bonnet weight 200% or more—an indication of the mass, and hence radiating area, of the air-fin bonnet.



Longer, stronger stem is approximately 55% heavier—to offset loss of tensile strength under extreme temperature.

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VOLUME 19, No. 11 NOVEMBER, 1940

REFINER
AND NATURAL GASOLINE
MANUFACTURER

A GULF PUBLISHING COMPANY PUBLICATION

The Look Box

TO MANY estimates and so few facts are the mixture, which brings all the confusion as to what the petroleum industry, especially refining, must provide in the national defense program. In the belief that the best advice comes from the man in the best position to know, REFINER AND NATURAL GASOLINE MANUFACTURER below offers the latest statement of Dr. Robert E. Wilson, Raw Materials Division, Advisory Commission to the Council of National Defense.

Gasoline and Defense Today

These paragraphs are from his address, "Synthetic Hay for Our War Horses," before the first general session of the twenty-first annual meeting of the American Petroleum Institute, November 13, in Chicago:

"In refining, the possibilities of immediate expansion of output to meet sharp increases of demand is not as great as in production; but, nevertheless, our civilian demand is so large that it still dwarfs every possible military demand except that for a few special products. Few, even in the industry, realize that the increase in our gasoline production is more than twelvefold since 1915. Our shut-down refinery capacity today is greater and more efficient than our entire capacity in 1917. It would be possible, by rather moderate methods of reducing civilian consumption, to meet all military demands without any increase in refinery capacity, so that there seems to be no justification for asking the government to finance new refining capacity, as many seem to anticipate. However, I am sure the petroleum industry would not consider that it had done its duty by its customers if this had to happen. When in cities like Chicago and St. Louis from 40 to 55 percent of the individuals entering the central zone of the city do so by means of gasoline, we cannot lightly talk of curtailing civilian consumption, as though it could be done as easily as in Europe. If we are to avoid such a possibility, we must at least keep our refineries growing fast enough to keep pace with the growth of peacetime consumption and keep customary reserve of around 20 percent of shut-down capacity available for possible wartime expansion. As new and more efficient refining equipment is developed and installed, the old should, so far as possible, be held in reserve for emergencies.

"Coming to the specific refinery products, the most probable bottleneck in our meeting the army and navy demands is also one of the most romantic stories of our industry, viz., synthetic 100-octane gasoline. Although the advantage of high-octane gasoline in making possible higher-compression engines has long been understood, the appreciation of its tremendous value for aviation purposes is somewhat more recent. In aviation, the more efficient high-compression engines have three advantages—first, a smaller fuel load; second, a lighter engine per horsepower; and,

third, less head resistance, due both to a smaller engine and a lower cooling load, because more heat is converted into work and less into heat to be rejected to the atmosphere. All of these mean higher speed and/or greater load-carrying ability, both of which are almost priceless for military purposes. For example, a difference of only 25 miles per hour in the top speed of two fighting planes gives the control of the attack or retreat to the faster plane.

"While ordinary motor gasoline was making its steady climb from 50- to 55- during the last war to around 75-octane at present, farsighted representatives of the military services and of our industry have been focusing their attention on the apparently unattainable goal of 100-octane for military aviation. Such fuel, which 10 years ago was available only in laboratory quantities at a price of $10 per gallon, can now be made by any one of several newly developed synthetic methods, and is available in large quantities at around 17 cents per gallon f.o.b. refinery. The raw materials for these synthetic processes are certain constituents of natural and refinery gas, available in suitable quantities in almost any large refinery. The final product usually contains some fairly high-octane straight-run gasoline and other constituents including not more than 3 ml of tetraethyl lead.

"Fortunately for the defense program, the petroleum industry, with its genius for overbuilding, has already installed synthetic capacity beyond the present domestic and foreign demands, so there is today substantial excess capacity available for the building up of a reserve for possible war demand. The installed capacity is, however, barely enough to meet our probable peactime requirements, including exports, once our advanced training program is well under way, and is substantially less than enough to meet present estimates of full wartime demand after our plane-building program is complete. Revised specifications have just been issued which should increase the quantity available without any adverse effect on performance. The importance of building a stock pile now, while we do have some surplus capacity, seems obvious, and a substantial start in this direction has recently been made by the army and navy. Even with such a stock pile, it would seem desirable from the defense viewpoint to have some additional capacity available within about 18 months, and I am hopeful that the industry will undertake such construction without government aid if we are able to arrrange to give such plants the benefit of the 5-year tax-amortization provisions. I hesitate to urge the industry to accumulate further stocks before the government really begins more substantial purchases, but the prospective demand is such that I would not be doing my duty by either the government or by the industry if I did not urge that all existing plants be operated and no more synthetic product be diverted to motor fuel. Additional synthetic capacity could also make it possible to further improve the octane rating of the gasoline used by the military service, or it could be used to increase the quantity of 91-octane available for training purposes.

"Gasoline of 91 octane number (formerly 92-octane) is to be the main reliance for more than half of the training activities of the services, and will also be rather widely used by the airlines and as a constituent (along with synthetic blending stock) of 100-octane gasoline. This product may also be a bottleneck by the time the training program gets well under way about a year from now. Inasmuch as this product, which may now contain up to 4 ml of tetraethyl lead, is largely a product of selected crudes with the possibility of adding substantial amounts of catalytically cracked or hydroformed gasoline, the possible shortage problem can be solved in various ways—including, if necessary, the granting of increased allowables for crudes which have a high content of aviation gasoline. Here, again, it appears desirable for the government to build up substantial stocks of this material in order to take advantage of present low prices and to minimize later dislocations of the industry; but the matter is not as urgent as in the case of 100-octane gasoline. Again, however, I hope the industry will conserve all available supplies of 91-octane aviation gasoline."

Dollar Economy Without Sense

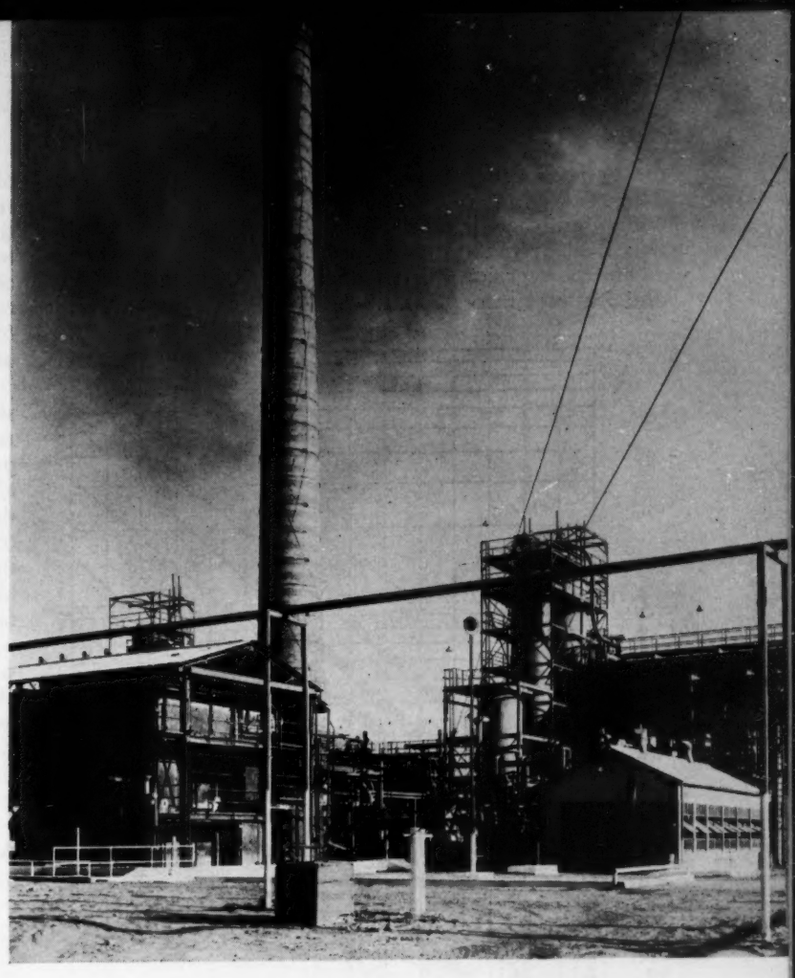
LATEST proponent of alcohol as a part of motor fuel is Michigan Congressman Tenerowicz, who admits that 10 percent of alcohol in gasoline would increase the cost of motor fuel to the American people by $690,000,000 each year. He wants the increase as a source of higher income to the farmer, whose products would go to make the 10 percent of alcohol.

In analyzing the proposal, J. J. Cavanaugh, vice president of the Chicago Motor Club, pointed out that since farmers use one-fourth of the nation's motor fuel, they would pay $172,000,000 for the benefit, and that only $187,000,000 of the $690,000,000 of added cost could get back to the farmer as net profit.

So the farmers as a whole would benefit by $15,000,000, while other automobile owners would be forced to pay $528,000,000 added motor fuel cost in order to bring so little benefit to farmers.

HIGH yields of motor fuels with CFR-ASTM octanes from 70 to 80 are obtained from Gas Reversion and Polyform operations. Theoretical discussion of improved gas-naphtha conversion results obtained in these processes is presented. Cooperation is obtained with mixed propanes, butanes, and naphtha, and polymerization, alkylation, and other synthesis reactions take place. The dilution of naphtha with gases has a pronounced physical effect on naphtha reforming permitting increased conversion per pass with less tendency towards coke formation. Commercial application, operating flow sheets and data from Polyform and Gas Reversion Units are presented. Equipment and operation of these units, as well as the distillate treating, are conventional and similar to thermal cracking. Commercial operations extend over 4 years with 10 units now operating and 2 units under construction which will process altogether 55,000 barrels per day of naphtha and outside propanes and butanes. The gasoline obtained from Polyform-Gas Reversion Processes, in addition to increased yields and octanes, has good distillation characteristics and lead response. Economic realizations from the presented curves of investment and operating costs give these refining methods a place in the industry.

This paper was delivered at the Twenty-first Annual Meeting of the American Petroleum Institute, Chicago, November 11-15, 1940.



Naptha-Gas Reversion Unit, Phillips Petroleum Company's Borger, Texas, Refinery.

The Naphtha Polyform and Gas Reversion Processes

J. E. BOGK, Phillips Petroleum Company
P. OSTERGAARD, Gulf Oil Corporation
E. R. SMOLEY, The Lummus Company

DURING the past 10 years anti-knock improvement of motor fuel has been an important factor in the trend toward better performance. Early improvement was along conventional lines, incorporating increased application of cracking, with attendant improvements in still design, and the use of thermal reforming. More recently the octane number levels reached, have made it necessary to turn more and more to new processes. Catalytic and thermal gas polymerization are now in extensive use for augmenting motor fuel yield and raising the overall octane number, and recently, catalytic cracking has been applied. Most of the new processes when used in conjunction with cracking operations, provide more than merely additive improvement; a polymerization unit, for example, permits production of a higher-octane-number gasoline with a reduced penalty in the form of gas loss. However, in fully combining thermal cracking or reforming with thermal gas polymerization to effect both conversions wholly or partially in the same reaction zone, it has been found possible to materially elevate octane levels and improve economics well above those obtainable by conducting the conversion steps separately. These processes, generally speaking, are carried out in more or less conventional thermal equipment and their effectiveness depends upon conducting the conversion steps under proper conditions. This paper is concerned with the joint conversion of naphtha and hydrocarbon gases to produce high yield of motor fuel with octane numbers in the range of 70 to 80 CFR-ASTM.

Chemistry of Gas-Naphtha Conversion

A brief review of the chemistry of gas polymerization will aid in explaining the joint conversion of gas and naphtha.

The thermal conversion into gasoline of propane, butane and the gaseous olefins, which represent the convertible part of still gases, is effected by heating them either singly or in mixture to a temperature in the range of 800 to 1150° F. while maintaining a pressure of 500-3000 pounds per square inch in the reaction zone.

Concentrated gaseous olefins—ethylene, propylene, butylene—polymerize directly into a high yield of

motor fuel, the product being mainly higher olefins. The reaction is accelerated by pressure, and above 500 pounds will take place at or even below the usual oil cracking temperatures.

The conversion of the gaseous paraffins, propane and butane, into gasoline is more complicated. The

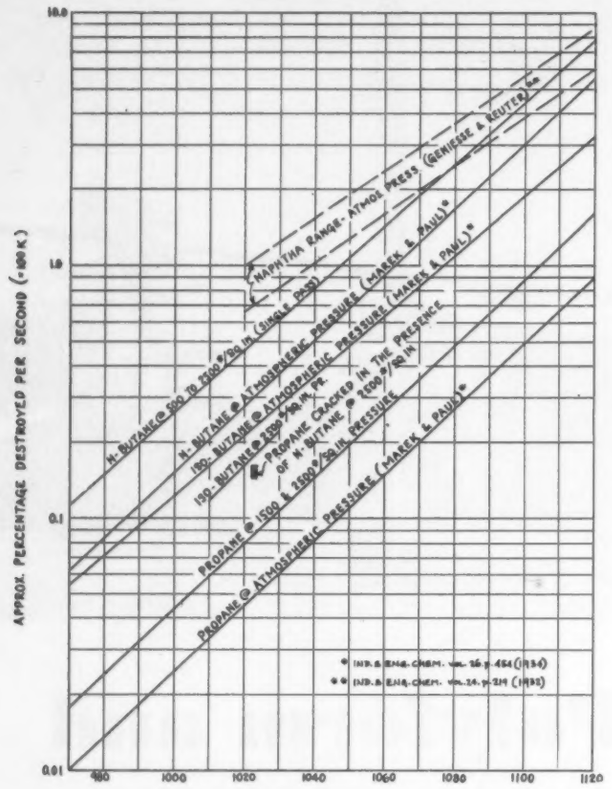

APPROX. PERCENTAGE DESTROYED PER SECOND (=100 K)
10.0
1.0
0.1
0.01
980
1000
1020
1040
1060
1080
1100
1120
NAPHTHA RANGE - ATMOS PRESS (GENESEE & REUTER)**
N-BUTANE @ 500 TO 2500 #/SQ IN (SINGLE PASS)
N-BUTANE @ ATMOSPHERIC PRESSURE (MAREK & PAUL)*
ISO-BUTANE @ ATMOSPHERIC PRESSURE (MAREK & PAUL)*
ISO-BUTANE @ 2500 #/SQ IN. PR.
& PROPANE CRACKED IN THE PRESENCE OF N-BUTANE @ 2500 #/SQ IN
PROPANE @ 1500 & 2500 #/SQ IN PRESSURE
PROPANE @ ATMOSPHERIC PRESSURE (MAREK & PAUL)*
* IND. & ENG. CHEM. Vol. 26 p. 454 (1934)
** IND. & ENG. CHEM. Vol. 24. p. 219 (1932)

FIGURE 1
Cracking Velocity Constants of Propane, Butane and Naphtha.

paraffin first breaks up into smaller paraffin and olefin molecules, then the olefin molecules so formed undergo conversion into gasoline through concurrent olefin-olefin polymerization and olefin-paraffin union or alkylation reactions. By cracking at low pressure it is possible to convert propane or butane almost completely into lighter gaseous olefins and paraffins, but when the pressure is high the polymerization of these olefins follows closely on the heels of the cracking reaction and gasoline begins to form when only a small part of the original paraffin has been decomposed. As the time of residence in the cracking zone is increased, progressively larger quantities of gasoline range hydrocarbons are formed, the gasoline becomes richer in cyclic hydrocarbons, tar formation then begins and accelerates, until carbon formation becomes evident. The onset of carbon formation, as in conventional cracking, sets a definite limit on the fraction of the original paraffin that can be decomposed per pass at high pressure in the conversion zone, making it necessary to recycle unreacted hydrocarbons in order to obtain highest gasoline yields. The lightest products, methane and ethane, crack with great difficulty and, considered from the yield standpoint, should not be present in excessive amounts in the furnace charge. Olefins, as well as paraffins in the C_3-C_4 range, are suitable for recycling.

The yield of gasoline depends on the composition of the charging stock, the temperature, pressure and reaction time. Within limits, temperature and reaction time are interchangeable, short times and high temperatures giving approximately the same yield of gasoline as long times and low temperatures in recycle operation. Drastic time-temperatures make for a product rich in aromatics and with a high octane number.

The individual paraffins differ widely in their resistance to the initial decomposition, becoming more refractory as their molecular weight decreases. Thus, propane requires about four times the reaction time at a given temperature to effect a stated amount of decomposition as does n-butane. Mixtures of propane or butane with olefins form gasoline at conditions intermediate to those for either olefins or paraffins alone and are responsive to high pressures, which favor alkylation reactions and high yields.

The decomposition rates of propane and butane, as well as some naphthas, are shown plotted against temperature in Figure 1. These constants were calculated by substituting the proper values in the equation for a first-order reaction:

$$k = \frac{2.303}{t_{(sec)}} \log \frac{100}{100-x}$$

where t is reaction time in seconds and x is the percent of the hydrocarbon destroyed. The values of

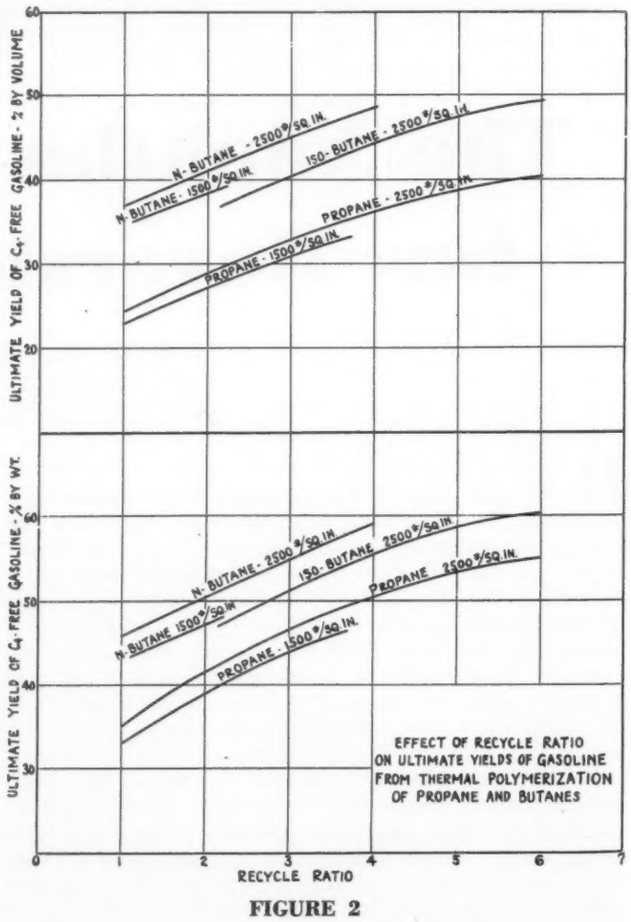


FIGURE 2

t and x have been determined experimentally by maintaining the hydrocarbons under known conditions of temperature and time and determining the extent of decomposition from analyses of the products obtained. The decomposition rate doubles for

an increase in temperature of 25-30° F. The effect of pressure on the decomposition rate of saturated material is small. High pressure serves mainly to accelerate the gasoline-forming olefin polymerization and alkylation reactions, and highest per-pass as well as ultimate gasoline yields are obtained at the highest pressures. At a pressure of 2500 pounds per square inch a per-pass gasoline yield amounting to approximately 15 and 8 percent by liquid volume from butane and propane, respectively, can be obtained before carbon formation becomes marked. At somewhat lower pressures, 1000-1500 pounds, the maximum obtainable gasoline yield per pass decreases slightly.

In Figure 2 are shown the ultimate yield of gasoline from propane and butane cracked at 2500 and 1500 pounds pressure plotted against the recycle ratio resulting when all of the C_3 and C_4 hydrocarbons surviving passage through the reaction zone are recycled. These values were calculated from single-pass experimental data and the range covered is fairly broad. Carbon formation probably would be encountered if propane were cracked with low recycle ratios in the order of one or two. The trends shown indicate a marked yield improvement as conversion per pass is decreased, i.e., recycle ratio increased.

The charging stock composition affects not only the yield but the character of the gasoline formed. The gasoline-forming reactions must proceed under the same time-temperature conditions as are needed to effect the initial decomposition of the original charging stock. Consequently, gasoline formed by cracking propane under high conversion conditions has been subjected to much more drastic conditions of time-temperature than a similar product from n-butane. As a result of this, the gasoline from propane cracking usually will contain larger percentages of the heat-stable cyclic and aromatic compounds.

The reactions leading to the formation of gasoline and heavier products are complex and not well understood. As stated previously, olefins when in concentrated form readily polymerize to yield higher-boiling products which are largely olefinic. This reaction is sensitive to pressure, and as the concentration of the olefins is reduced by paraffin diluents, higher pressures are required to maintain reaction velocity. If reaction temperature is increased the tendency to form cyclics which may dehydrogenate to aromatics becomes marked. The olefin polymerization reaction velocity is doubled for a temperature increase of approximately 45° F. This compares with 30° F. to double the initial decomposition reactions. Consequently, as temperature is increased cracking tends to outstrip the polymerization and the olefin content of the effluent gases from the reaction coil increases.

In addition to olefin-olefin polymerization, alkylation reactions wherein gaseous olefins, particularly ethylene, react directly with paraffins to yield higher-boiling paraffins also proceed. These reactions are also accelerated by increased pressure and temperature, the rate doubling for a temperature increase of approximately 40° F. Under favorable conditions of high pressure, moderate temperature and high cycle ratio, a substantial part of the gasoline may be formed through these alkylation reactions.

Products boiling above the gasoline range probably are formed from the gasoline through a series of reactions involving olefin polymerization, cyclization, aromatization, and condensation. Coke formation closely follows tar formation and probably results from the coking of high-boiling tars which have reached their dew-point and are precipitated on the tube walls.

TABLE 1
Commercial Operating Data of Naphtha Gas Reversion Units

	Run No. 1	Run No. 2	Run No. 3	Run No. 4	Run No. 5
Charge:					
Naphtha, %	100.0	100.0	100.0	100.0	100.0
Outside gas feed, % on naphtha	100.0	100.0	100.0	100.0	100.0
Total charge, % on naphtha	200.0	200.0	200.0	200.0	200.0
Gasoline Yield: (Based on naph. charge)					
Percent 8.5 PSI RVP at 100°	135	131	134	128	119.5
API gravity	61.3	59.5	62.0	61.5	59.8
Distillation, ASTM:					
IBP	95	95	93	98	98
10%	125	143	123	132	137
50%	204	224	210	204	203
90%	353	347	345	339	321
E.P.	402	410	406	408	405
Sulfur (lamp)	.06	.02	.09	.10	.09
CFR-ASTM Oct. No.	69.2	67.3	69.0	73.0	75.5
+1 cc TEL/gal. at 6.5 lbs. R.V.P.	74.2	73.6	74.0	77.1	79.1
+2 cc TEL/gal. at 6.5 lbs. R.V.P.	78.0	78.0	78.0	79.8	81.2
+3 cc TEL/gal. at 6.5 lbs. R.V.P.	80.5	80.6	80.5	81.0	82.6
Fuel Oil Yield:					
% on naphtha—Average 3%					
API Gravity 12.0					
SFV at 122 °F. 90.0					
BS&W 0.2					
Naphtha Charge:					
Gravity, °API	60.6	61.1	60.6	59.6	58.7
Distillation, ASTM:					
IBP	110	99	110	105	104
10%, °F.	156	150	160	157	162
50%	244	242	250	255	261
90%	364	366	375	400	410
E.P.	424	423	428	446	450
% Evap. at 212 °F.	....	34	....	31	....
Aniline point	133.2	132.8	133.9	136.2	134.2
% Sulfur (lamp)	....	....	....	.12	.11
CFR-ASTM Oct. No.	49.0	46.4	47.8	....	49.4
Outside Gas Feed:					
Analysis, L.V. %					
H_2	....	....	....	....	....
C_1	2.7	0.6	2.8	2.8	2.6
C_2	9.7	2.9	11.0	23.9	13.9
C_2=	0.7	0.2	1.0	1.5	0.5
C_3	44.9	12.5	52.3	54.4	38.6
C_3=	5.5	2.7	4.7	15.2	5.9
C_4 s	32.2	74.3	26.0	2.2	35.5
C_4= s	3.9	6.6	2.0	....	2.9
C_5 s	0.4	0.2	0.2	....	0.1
Total unsaturates, L.V. %	10.1	9.5	7.7	16.7	9.3
Sulfur (lamp)	....	....	....	0.83	0.44%

Conversion of Gases Plus Naphtha

Single Stage Conversion:

An inspection of Figure 1 brings out that naphtha is much less refractory than saturated propane or butane. A mixture of naphtha and propane, for example, must be converted at a time-temperature no more than sufficient to effect extensive once-through reconstructing of the naphtha, short of coking. This automatically dictates a limited destruction of the accompanying propane, which for its complete conversion, must be recycled in a volume 7 to 10 times the net volume supplied. Butane, being less refractory, requires a 3-to-5 ratio. These ratios are somewhat lower than would be calculated for the individual velocity constants given in Figure 1, since in mixtures some cooperation is obtained, in that cracking velocity of the propane and butane is increased, and these hydrocarbons also are consumed by alkylation and other synthesis reactions. Figure 2 brings out that high recycle ratios make for high ultimate gasoline yield from gaseous paraffins.

The admixed gases in addition have a pronounced physical effect on the naphtha reforming which takes place concurrently with gas polymerization. In reforming naphtha alone, the octane number of the motor fuel increases as the severity of the thermal treatment increases up to the point where coke

formation sets in, placing a limit on the degree of conversion. Coke formation usually is ascribed to the development of tar in increased amount and of increasingly high dew-point which at length deposits as a liquid phase and goes to coke *in situ*. The reduction of partial pressure deters tar condensation, and at pressures of 1000 pounds more or less, the gases tend to further deter tar deposition by reducing the critical temperature and lowering the dew-point.

For the reasons given, conversion conditions at 1000 pounds pressure, for example, can be made quite drastic with attendant octane-number improvement, when gas conversion stock is admixed with naphtha in sufficient relative amount, usually in excess of volume for volume, to produce the physical effects described. The chemistry of the joint conversion reaction is imperfectly understood. It is certain that

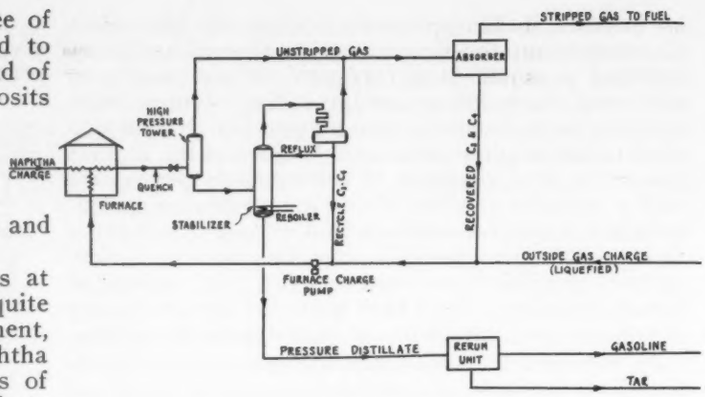


FIGURE 3
Schematic Flow Diagram—Naphtha-Gas Reversion Unit.

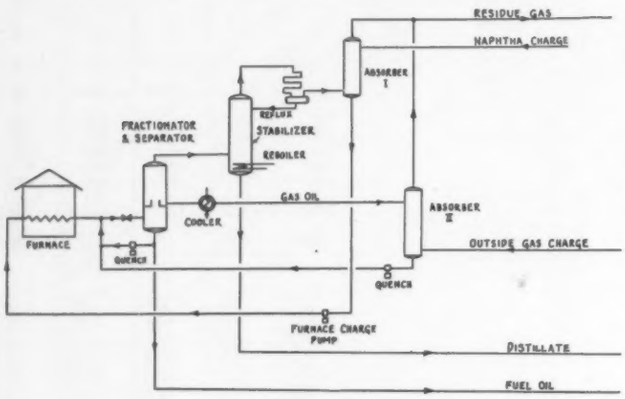


FIGURE 4
Schematic Flow Sheet—Naphtha Polyform Unit.

a large fraction of the naphtha, with drastic but non-coking conditions, is converted into gaseous olefins and some paraffins. These, together with the gaseous hydrocarbons introduced, undergo gas polymerization with olefin polymerization predominating and alkylation taking place to a minor degree. As more naphtha breaks up, more polymer gasoline forms, supplementing the gasoline resulting from reconstructing reactions of the naphtha itself.

Mild operating conditions are indicated when higher yield at a lower octane-number level is the result desired. Gas loss from the naphtha can in this way be reduced. However, as even more lenient conditions are imposed on the gas conversion, a point can be reached where the recycle ratios for butane and propane are economically excessive and only gaseous olefins can contribute substantial polymerization per-pass yields. This process is inherently limited in flexibility with respect to gaseous feed stock to the extent that the naphtha dictates either its volume or convertibility, but ordinarily presents a favorable picture at high octane levels and with readily convertible or internally produced gas feed.

Two Stage Conversion:

In another process arrangement to be discussed the gas conversion stock passes first through a thermal polymerization coil, naphtha is admixed, and the blended stream passes through a second coil where joint conversion is effected.

In this modification the reaction conditions set forth above in connection with gas polymerization are applicable to the gas conversion step. The second stage differs from the naphtha-gas conversion step mainly in respect to two features—the incoming gases may contain tar in appreciable amounts and polymer gasoline is present. The severity of the conversion applied to the naphtha needs to be moderated to minimize polymer destruction when the preceding gas conversion has been severe enough to produce tar, which sets back the coking threshold. Gas tar can be reduced or effectively eliminated by retreating a short way from optimum per-pass yield in the polymerization step; this process then approaches the single-stage process.

Desirable conversion conditions in the polymerization step can be selected for any composition of gaseous feed. To produce maximum yields and intermediate octane number, this process allows of independently moderating conversion conditions on the naphtha to any degree, relying on the gas conversion step to convert the gas efficiently.

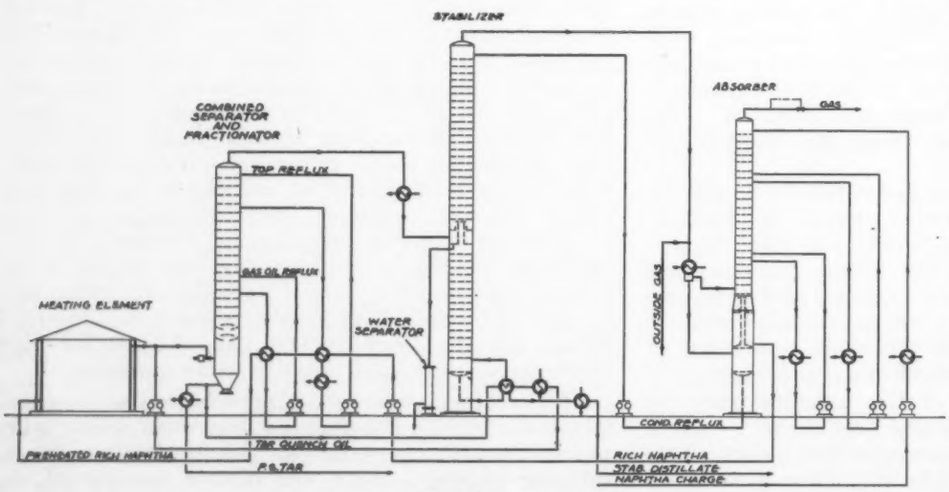


FIGURE 5
Naphtha Polyform Unit.

Commercial Application of Gas-Naphtha Conversion

The two processes presented in the paper, namely naphtha gas reversion and naphtha polyforming, are thermal processes in which the naphtha to be reformed is converted into 70- to 80-CFR-ASTM-number gasoline in a conversion zone in a mixture with C_3 and C_4 hydrocarbons. The residue gas from these operations is practically free of butane and has a specific gravity varying from .65 to 0.9 depending upon desired propane conversion. The two processes differ in the way the naphtha is introduced into the furnace stream. With the gas reversion process the C_3 and C_4 hydrocarbon furnace charge is first subjected to a partial conversion before the preheated naphtha is injected into this steam. The final conversion, polymerization, and other side reactions of and between the gaseous hydrocarbons and the naphtha take place in a common soaking section. With the naphtha polyform process, a mixture of naphtha and C_3 and C_4 hydrocarbons is preheated and passed together through the entire heater coil. The conversion, polymerization, and other side reactions of and between the gaseous charge and the naphtha progress concurrently. Various modifications and combinations of the foregoing have been adopted commercially and provide efficient utilization of the principles of gas-naphtha conversion. Maximum results have been secured from the various combinations of stocks that have been available. This includes the conversion to gasoline of appreciable quantities of saturated propane and butane.

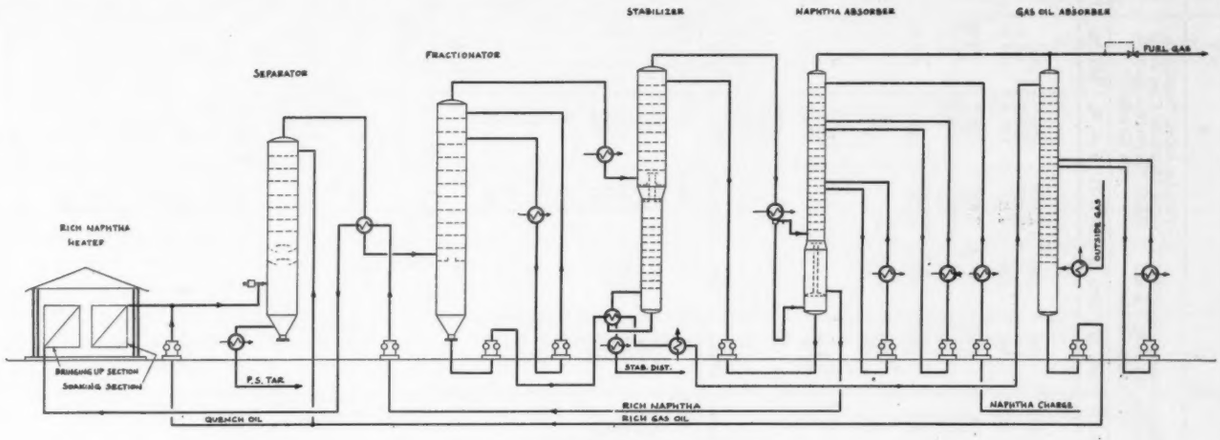


FIGURE 6
Naphtha Polyform Unit With Outside Gas Charge.

Figures 3 and 4 represent the basic flow diagrams of these two processes. The reversion process combines a virgin and a recycle liquefied gas fraction, which is first preheated and then passed through the gas conversion portion of the coil where time-temperature conditions are varied in accordance with the composition of the stock. The preheated naphtha stream is injected into the gaseous stream at the optimum point and the mixture then passes through the remainder of the coil where proper conditions are maintained to effect further gas conversion reactions simultaneously with conversion of the naphtha. Coil outlet products are cooled through charge-stock exchangers where quench oil is introduced as a temperature-control medium. Subsequent fractionation is arranged to release uncondensable gases in the first step with the recovery of C_3 and C_4 recycle liquid and resultant stabilization of product occurring in the second step. Depending upon the desired degree of propane conversion, recycle liquefied gas may be recovered by absorption from the stabilizer and possibly the high-pressure tower residue gas streams. The stabilizer bottoms are separated into gasoline, quench oil, and fuel oil by a rerun operation. The absorption and rerun steps may or may not be incorporated in the unit proper.

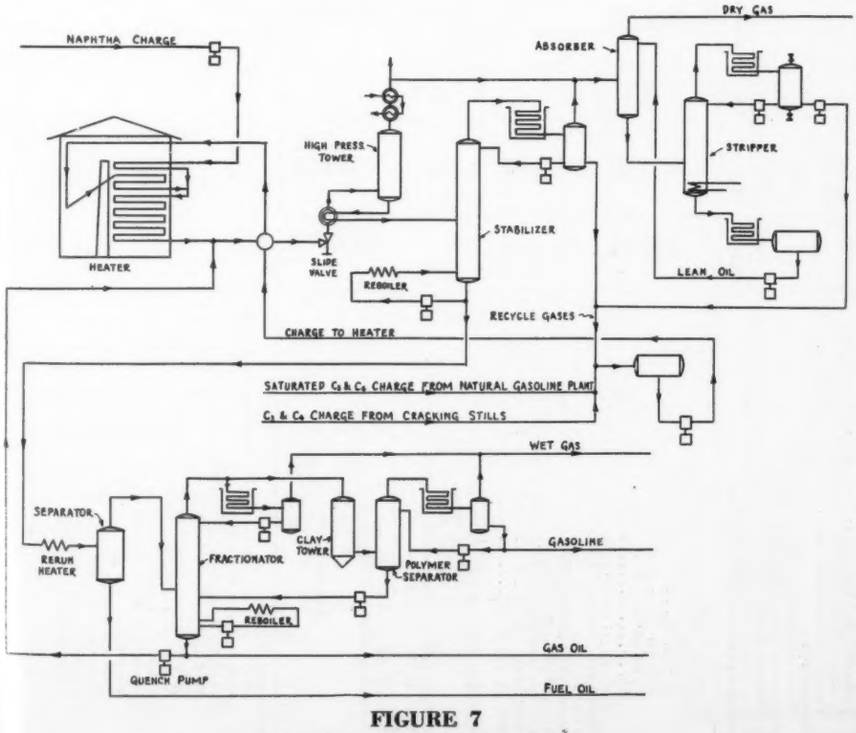


FIGURE 7
Naphtha Gas Reversion Unit.

The polyform flow utilizes the

TABLE 2

YIELDS, PRODUCTS AND OPERATING DATA OF NAPHTHA POLYFORM UNITS WITH AND WITHOUT OUTSIDE GAS

	1			2			3			4			5			6		
	Polyforming Naphtha —5% (23.5-28.5% on E. Venez. Crude)			Polyforming Naphtha 10%— (18.6-28.5% on E. Venez. Crude)			Polyforming Naphtha —15% (13.4-28.5% on E. Venez. Crude)			Polyforming Naphtha —10% (18.6-28.5% on E. Venez. Crude			Polyforming Naphtha with Outside Gas Feed (M.C. Naphtha 20-32% on Crude)			Polyforming Naphtha with Outside Gas Feed (M.C. Naphtha 26-34% on Crude)		
Operation Number	**Bbl./D**	**Vol. %**	**Wt. %**	**Bbl./D**	**Vol. %**	**Wt. %**	**Bbl./D**	**Vol. %**	**Wt. %**	**Bbl./D**	**Vol. %**	**Wt. %**	**Bbl./D**	**Vol. %**	**Wt. %**	**Bbl./D**	**Vol. %**	**Wt. %**
I. OPERATING DATA:																		
Charge:																		
Naphtha	4,000	100	100	4,000	100	100	4,000	100	100	4,000	100	100	2,515	100	100	1,111	100	100
Outside gas (F.O.E.)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2,286	90.9	96.9	1,894	170.5	188.9
Total	4,000	100	100	4,000	100	100	4,000	100	100	4,000	100	100	4,801	190.9	196.9	3,005	270.5	288.9
Yields:																		
Gasoline	3,040	76.0	74.3	3,350	83.9	82.0	3,470	86.8	85.5	2,580	64.6	64.4	2,480	98.6	94.98	1,337	120.3	113.7
Gas (F.O.E.)	467	11.7	11.7	360	9.0	9.4	336	8.4	9.0	709	17.7	19.5	2,118	84.22	88.43	1,565	140.9	156.9
Tar	446	11.3	14.0	296	7.4	8.6	180	4.5	5.5	540	13.5	16.1	198	7.89	10.27	83	7.5	9.9
Total	3,953	99.0	100.0	4,006	100.3	100.0	3,986	99.7	100.0	3,829	95.8	100.0	4,796	190.71	193.68	2,985	268.7	280.5
Temperatures, °F.:																		
Charge to furnace	.....	475	.....	.....	475	.....	.....	475	.....	.....	425	.....	.....	425	.....	.....	360	.....
Product from furnace	.....	1,090	.....	.....	1,080	.....	.....	1,085	.....	.....	1,125	.....	.....	1,075	.....	.....	1,040	.....
Pressures, Lbs./Sq. In.:																		
Charge to furnace	.....	1,250	.....	.....	1,250	.....	.....	1,250	.....	.....	1,250	.....	.....	1,250	.....	.....	1,550	.....
Products from furnace	.....	1,000	.....	.....	1 000	.....	.....	1,000	.....	.....	1,000	.....	.....	1,000	.....	.....	950	.....
Fractionating system	.....	300-350	.....	.....	370-400	.....	.....	300-350	.....	.....	300-350	.....	.....	350	.....	.....	370-290	.....
Quantities:																		
Rich naphtha circulation, B/D	.....	9,220	.....	.....	9,000	.....	.....	9,030	.....	.....	12,100	.....	.....	12,100	.....	.....	6,660	.....
Gaseous charge M-CFD	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7,480	.....	.....	6,310	.....
Residue gas M-CFD	.....	2,620	.....	.....	2,025	.....	.....	1,910	.....	.....	4,220	.....	.....	8,420	.....	.....	6,440	.....
LABORATORY INSPECTION:	**Charge**	**Dist.**	**Tar**	**Charge**	**Dist.**	**Tar**	**Charge**	**Dist.**	**Tar**	**Charge**	**Dist.**	**Tar**	**Charge**	**Dist.**	**Tar**	**Charge**	**Dist.**	**Tar**
Gravity, °API	45.7	50.0	16.1	47.9	52.0	22.9	50.8	53.9	17.4	47.9	48.5	18.8	51.8	58.8	9.5	51.3	61.9	8.7
Distillation, ASTM:																		
O.P at, °F	318	92	355	266	100	375	230	96	348	266	98	352	160	91	.....	158	91	.....
E.P. at, °F	465	412	.....	431	404	.....	412	400	.....	431	406	.....	446	409	.....	426	378	.....
10 percent at, °F	329	146	386	290	152	419	258	140	393	290	152	408	236	126	.....	255	106	.....
50	349	298	500	311	282	510	286	259	511	311	270	518	324	228	.....	325	196	.....
90	409	372	.....	372	349	.....	358	335	.....	372	336	.....	407	366	.....	380	330	.....
Reid vapor pressure, lbs./sq. in.	.....	9.1	.....	.....	8.2	.....	.....	10.0	.....	.....	7.5	.....	.....	.....	.....	1.7	10.2	.....
Color	.....	+1	.....	.....	+1	.....	.....	+14	.....	.....	+2	.....	+18	+30	.....	+26	+30	.....
Gum—ASTM, mg/100 cc	.....	5	.....	.....	7.4	.....	.....	6.0	.....	.....	.....	.....	.....	1	.....	.....	5	.....
Copper dish, mg/100 cc	.....	85	.....	.....	55	.....	.....	12	.....	.....	.....	.....	.....	10	.....	.....	79	.....
Oxygen stability (E.G.C.) min. at 210 °F	.....	190	.....	.....	180	.....	.....	165	.....	.....	155	.....	.....	45	.....	.....	30	.....
Acid heat, °F	3	96	.....	2	89	.....	2	92	.....	.....	101	.....	2	95	.....	3	115	.....
Aniline point, °F	126	65	.....	136	71	.....	116	71	.....	.....	39	.....	136	96	.....	130	85	.....
Viscosity, SUV at 100 °F, sec	.....	.....	49	.....	.....	41	.....	.....	48	.....	.....	47	.....	.....	1,044	.....	.....	447
210 °F. sec	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
130 °F, sec	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Carbon residue, Conradson, percent	.....	.....	7.4	.....	.....	3.3	.....	.....	6.5	.....	.....	8.1	.....	.....	5.9	.....	.....	12.78
B. S. & W., percent	.....	.....	0.2	.....	.....	0.2	.....	.....	0.2	.....	.....	0.6	.....	.....	0.2	.....	.....	0.25
Pour, °F	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Flash Point (P.M.), °F	.....	.....	140	.....	.....	164	.....	.....	152	.....	.....	160	.....	.....	.....	.....	.....	.....
Octane number, ASTM, clear	40.9	76.6	.....	47.3	76.1	.....	49.7	76.1	.....	47.3	80.1	.....	39	75.2	.....	36.9	76.7	.....
+1 cc. TEL	50.0	81.3	.....	56.9	82.0	.....	59.6	82.7	.....	56.9	83.7	.....	.....	80.8	.....	.....	80.7	.....
+3 cc. TEL	60.6	83.8	.....	66.1	84.4	.....	70.5	85.1	.....	66.1	85.6	.....	.....	83.4	.....	.....	83.5	.....
Research, clear	46.0	88.7	.....	50.1	86.4	.....	51.5	85.5	.....	50.1	92.7	.....	.....	88.0	.....	.....	88.2	.....
+1 cc. TEL	49.8	93.7	.....	58.3	91.2	.....	60.1	92.2	.....	58.3	96.4	.....	.....	92.1	.....	.....	92.0	.....
+3 cc. TEL	62.5	95.6	.....	70.0	94.8	.....	71.3	94.8	.....	70.0	98.0	.....	.....	94.7	.....	.....	95.0	.....
GAS ANALYSIS:	**Feed**	**Residue**		**Feed**	**Residue**		**Feed**	**Residue**		**Feed**	**Residue**		**Feed**	**Residue**		**Feed**	**Residue**	
Specific gravity (Air =1)	.....	0.708	.....	.....	0.732	.....	.....	0.690	.....	.....	0.671	.....	1.11	0.918	.....	1.18	0.959	.....
Composition, percent by volume:																		
Hydrogen and methane	.....	63.6	.....	.....	60.9	.....	.....	6.54	.....	.....	68.4	.....	36.5	46.7	.....	30.2	41.5	.....
Ethene	.....	8.1	.....	.....	8.9	.....	.....	8.3	.....	.....	6.8	.....	2.6	5.4	.....	3.0	3.7	.....
Ethane	.....	26.4	.....	.....	27.8	.....	.....	24.3	.....	.....	23.0	.....	13.6	23.8	.....	18.6	25.8	.....
Propene	.....	.....	.....	.....	1.0	.....	.....	0.4	.....	.....	.....	.....	8.7	5.8	.....	10.2	7.2	.....
Propane	.....	1.9	.....	.....	3.4	.....	.....	1.6	.....	.....	1.8	.....	24.0	15.4	.....	19.4	16.2	.....
Butenes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.8	.....	.....	6.7	1.9	.....
Butanes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.5	2.9	.....	8.3	3.6	.....
Pentanes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.7	.....	.....	3.6	.....	.....
Hexanes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.4	.....	.....	.....	.....	.....
Unsaturates	.....	8.1	.....	.....	9.9	.....	.....	8.7	.....	.....	6.8	.....	.....	.....	.....	.....	.....	.....
Total	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	100	100	.....	100	100	.....

naphtha charge as an absorption oil to absorb the uncondensed C_3 and C_4 recycle from the residue gas leaving the stabilizer condenser. The liquefied C_3 and C_4 recycle stock from the stabilizer overhead condenser is mixed with the rich naphtha in the base of the absorber. The rich naphtha from the base of the absorber is preheated and then charged through the furnace. The effluent from the furnace is quenched with fractionator bottoms, flashed to remove tar and then fractionated and stabilized to end-point gasoline. The uncondensed residue gas and recycle stock from the stabilizer overhead condenser are the gaseous feed to the absorber.

With outside gas feed, a second absorber may be added for absorbing the C_3 and C_4 hydrocarbons from this source. Gas oil from the bottom of the fractionator is used as an absorbing medium. This enriched gas oil is then used as quench for the furnace outlet. By introducing the gaseous feed to the unit in this manner, any pentane and heavier hydrocarbons in the outside gas feed are fractionated out in the stabilizer bottoms products and are not included in the furnace feed. This prevents a yield loss due to conversion of pentane.

Operating conditions will vary according to the type of operation. For example, the naphtha gas reversion process normally will operate from 1020°F. to 1120°F. maximum in the gas conversion section, and 960°F. to 1060°F. maximum in the reversion section. Outlet pressure on the coil will vary from 1500 to 2200 pounds per square inch. The naphtha polyform process operates normally between 1025°F. and 1125°F. maximum temperature and around 1000 to 2000 pounds per square inch outlet pressure.

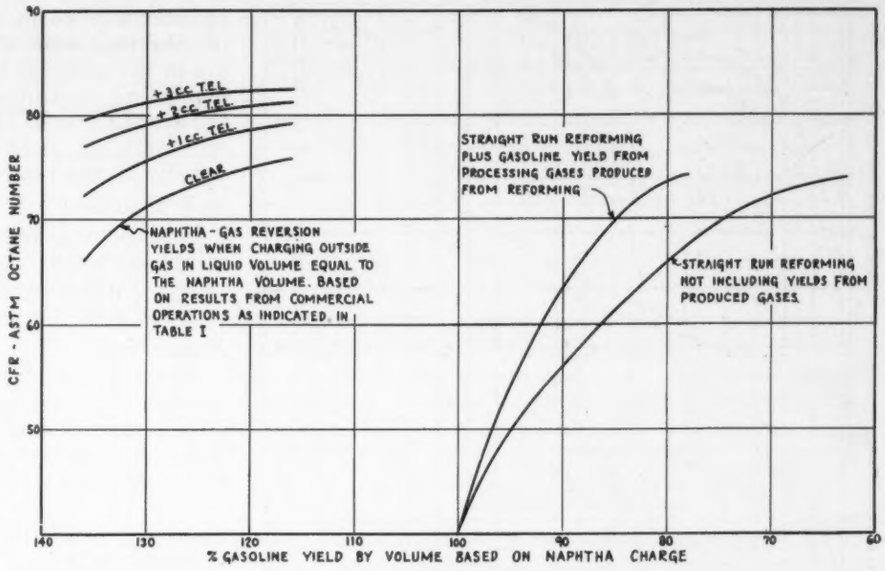

+3cc TEL
+2cc TEL
+1cc TEL
CLEAR
NAPHTHA - GAS REVERSION YIELDS WHEN CHARGING OUTSIDE GAS IN LIQUID VOLUME EQUAL TO THE NAPHTHA VOLUME. BASED ON RESULTS FROM COMMERCIAL OPERATIONS AS INDICATED IN TABLE I
STRAIGHT RUN REFORMING PLUS GASOLINE YIELD FROM PROCESSING GASES PRODUCED FROM REFORMING
STRAIGHT RUN REFORMING NOT INCLUDING YIELDS FROM PRODUCED GASES
CFR - ASTM OCTANE NUMBER
% GASOLINE YIELD BY VOLUME BASED ON NAPHTHA CHARGE

FIGURE 8

Yield-Octane Relationship for Naphtha-Gas Reversion and Reforming of Straight-Run Gasoline from Gray and Hutchinson County, Texas, Crude.

The equipment employed in both processes is entirely conventional, and, while furnace coils and transfer-line exchangers operate at high pressures, no difficulties have been experienced in the design, operation, or maintenance of this equipment. Separating and fractionating equipment are operated at pressures which permit the use of ordinary temperature cooling water for condensation, and also the absorption of recycle from residue gases without resorting to the use of recompression or refrigeration.

The gas reversion and polyform processes de-

TABLE 2-A

Yield Analysis From Polyforming Mid-Continent Naphtha With Outside Gas Charge

	5		6	
OPERATION	**Bbl./D**	**Vol. % Of Naphtha**	**Bbl./D**	**Vol. % Of Naphtha**
Charge:				
Naphtha	2,515	100.0	1,110	100.0
Outside gas F.O.E.	2,286	90.9	1,894	170.5
Total	4,801	190.9	3,005	270.5
Yields:				
Gasoline	2,480	98.6	1,337	120.3
Gas	2,118	84.2	1,565	140.9
Tar	198	7.89	83	7.5
Total	4,796	190.71	2,985	268.7
C_3 in outside feed gas	1,575	.....	1,197	.....
C_3 in residue gas	1,150	.....	972	.....
C_3 in net gas charge	425		225	
C_4 in outside feed gas	680	.....	698	.....
C_4 in residue gas	185	.....	220	.....
C_4 in net gas charge	495	.....	478	.....
Total C_3 and C_4 charge	920	.....	703	.....
C_5 in outside gas	110	.....	146	.....
Gasoline from:				
C_3 and C_4 gas feed	401	16.0	312	28.1
C_5+ in outside gas	110	4.4	146	13.2
Naphtha	1,969	78.2	879	79.0
Total	2,480	98.6	1,337	120.3
Ratio—C_3 and C_4: **Naphtha Feed**	.....	.365	.....	.635
Percent C_3 in net gas feed	.....	46.5	.....	32.0
Percent C_4 in net gas feed	.....	53.5	.....	68.0
Yields of distillate from C_3 and C_4 net gas charge	.....	43.5	.....	44.3
O.N. CFR-ASTM of total distillate	.....	75.2	.....	76.7

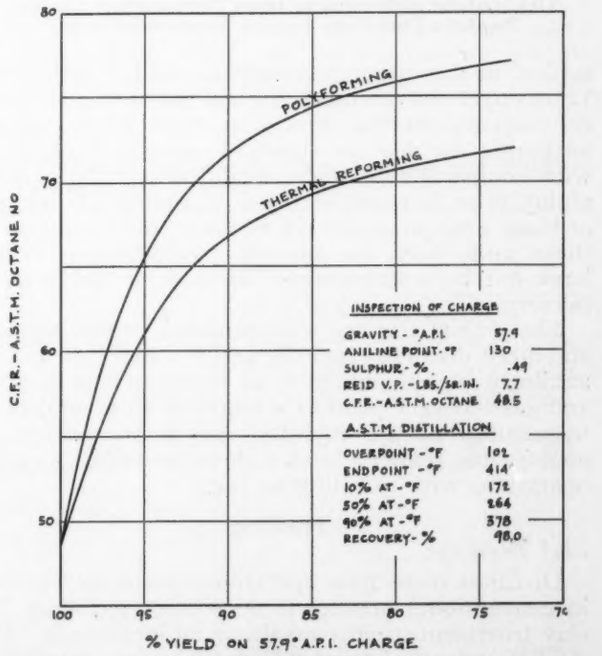

POLYFORMING
THERMAL REFORMING
C.F.R. - A.S.T.M. OCTANE NO
% YIELD ON 57.9° A.P.I. CHARGE
INSPECTION OF CHARGE
GRAVITY - °A.P.I. 57.9
ANILINE POINT - °F 130
SULPHUR - % .49
REID V.P. - LBS./SQ. IN. 7.7
C.F.R. - A.S.T.M. OCTANE 48.5
A.S.T.M. DISTILLATION
OVERPOINT - °F 102
ENDPOINT - °F 414
10% AT - °F 172
50% AT - °F 264
90% AT - °F 378
RECOVERY - % 98.0

FIGURE 9

Yield-Octane Relationship from Polyforming and Thermal Reforming of 57.9° API West Texas Gasoline.

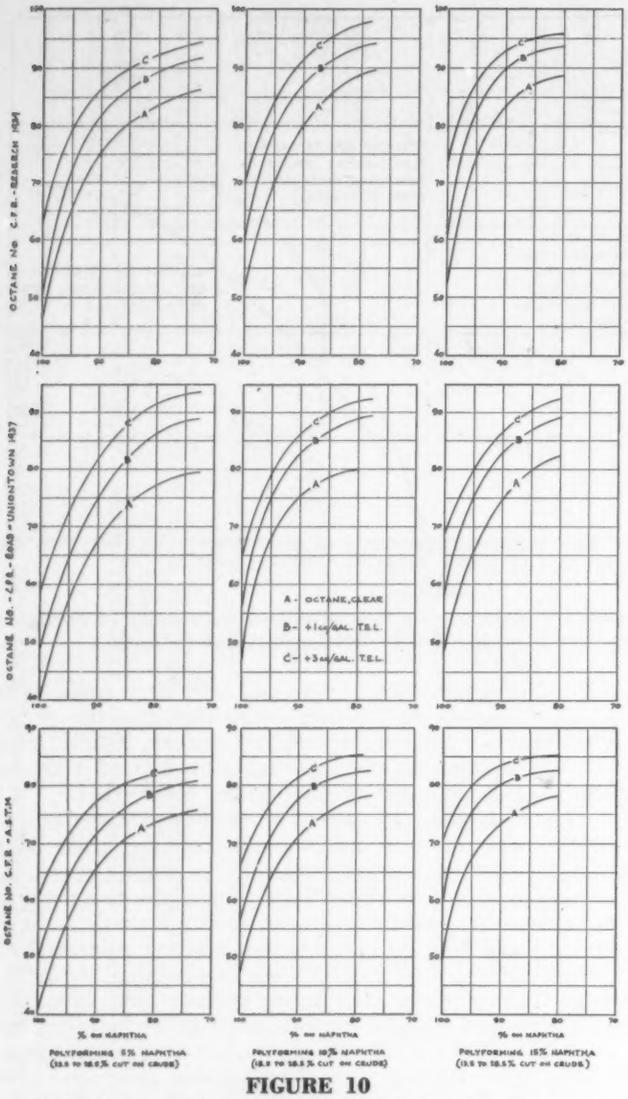


FIGURE 10

Yield-Octane Relationship from Polyforming Various Naphtha Cuts from Eastern Venezuela Crude.

scribed in this paper represent marked technical advances over conventional thermal polymerization and conventional thermal reforming, respectively, yet are adaptable for use in standard process equipment, with comparatively slight modification. This adaptability is in fact one of the outstanding advantages of these new processes. In addition, the operation of these units does not present any problems which have not been encountered already in the average refinery.

These units also are self-contained, producing only stabilized distillate, fuel oil, and dry fuel gas, and no auxiliary equipment such as distillate-stabilization and gas-recovery plants are required. In several cases installation of gas-naphtha conversion units have enabled the refinery to shut down existing gas-plant operations with resulting savings.

Treating

Clay Treating:

Distillate from these operations can be clay treated in conventional manner to 30+ color gasoline. The clay treatment usually results in an increase in CFR-ASTM octane of from 0.5 to 0.7 octane number, a decrease in acid heat and an increase in inhibitor response, inhibitor requirements being reduced approximately 25 to 50 percent, depending upon type of inhibitor used. The yields of clay-treated distillate are of the order of 3000 to 5000 barrels per ton of clay depending on sulfur content and other properties of the stock treated. The clay treating results in a slight reduction in yield due to production of polymers usually in the range of 0.5 to 2 percent.

Acid Treating:

High-octane polyform distillates can be acid treated to reduce acid heat, increase oxygen stability, reduce gum content, improve color stability and to increase load susceptibility.

Sweetening:

This type of distillate can be sweetened with conventional processes. Typical results of liquid copper sweetening of gas reversion distillates are shown in Table 5. It should be noticed that the octane number is not affected by sweetening.

Properties of Distillates

Octane Number and Tetraethyl Lead Response:

The octane-yield relationship of naphtha gas reversion distillates and naphtha polyform distillates is clearly indicated in Figures 8, 9, and 10.

In Figure 8 is shown the CFR-ASTM octane numbers of gas reversion distillates of various octane numbers ranging from 67.3 to 75.5, both clear and with 1 cc, 2 cc, and 3 cc per gallon of tetraethyl lead.

Figure 9 indicates the octane-yield relationship for a thermal-reformed distillate and a polyform distillate from the same stock, a 57.9° API West Texas gasoline with characteristics as shown. This figure indicates the large gain in either yield or octane number which may be obtained by the polyform operation.

Figure 10 illustrates the octane-yield relationship from polyforming naphthas of different boiling

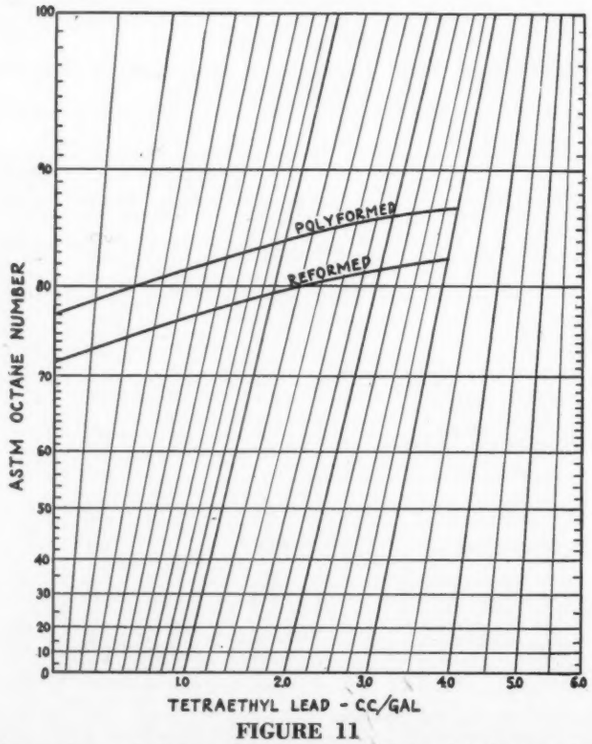


FIGURE 11

Comparison of Octane Numbers and Tetra-Ethyl Lead Susceptibility for Polyformed and Thermal Reformed Gasoline from 50/50 Mixture of Mid-Continent and Pennsylvania Naphtha for Same Yield.

TABLE 3

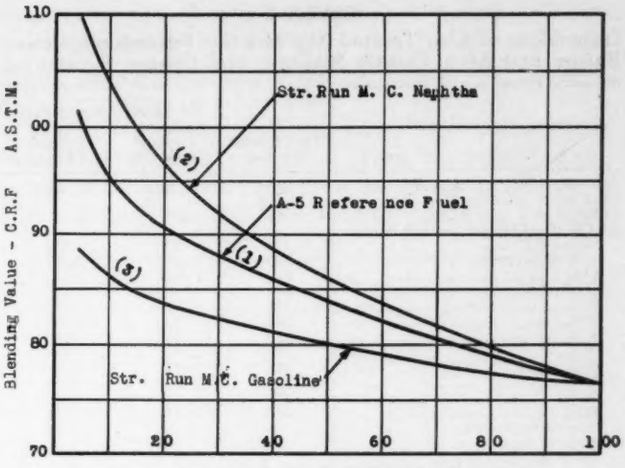
Properties of 5, 10 and 15 Percent Naphtha Cuts and of Total Gasoline Cut From Eastern Venezuela Crude

PERCENTAGE ON CRUDE	Naphtha 23.5 to 28.5	Naphtha 18.5 to 28.5	Naphtha 13.5 to 28.5	Total Gasoline 28.5
Gravity, °API	45.7	47.9	50.8	60.5
Vapor Pressure at 100 °F	.....	.....	.....	9.6
Aniline Point, °F	126	136	116	120
Acid heat, °F	3	2	2	3
Sulfur, B—%	0.05	0.03	0.01	0.01
ASTM Distillation:				
Over Point, °F	315	266	230	101
End Point, °F	465	431	412	412
10% at, °F	329	290	258	158
50% at, °F	349	311	286	240
90% at, °F	409	372	358	342
Octane Numbers:				
CFR-ASTM, Clear	40.9	47.3	49.7	59.9
+1 cc/gal.—TEL	50.0	56.9	59.6	.....
+3 cc/gal.—TEL	60.6	66.1	70.5	.....
CFR-Research, Clear	46.0	50.1	51.5	.....
+1 cc/gal.—TEL	49.8	58.3	60.1	.....
+3 cc/gal.—TEL	62.5	70.0	71.3	.....
Uniontown Road, clear				
+1 cc/gal.—TEL	.....	55.5	.....	.....
+3 cc/gal.—TEL	.....	67.5	.....	.....

ranges from Eastern Venezuela crude. The appreciation from the ASTM to Research and Road Octane Numbers is clearly illustrated by this figure. The CFR Road octanes and the CFR Research octanes of distillates of the same CFR-ASTM octane number from the different types of naphthas are of the same numerical order.

Figure 11 shows the lead susceptibility of a 71.7-octane CFR-ASTM distillate from thermal reforming of a 50-50 mixture of Mid-Continent and Pennsylvania naphthas compared with the lead susceptibility of a 77-octane number CFR-ASTM polyform distillate from the same naphtha charge.

The high octane number blending value, and general characteristics of gasoline from the thermal polymerization of C_3 and C_4 hydrocarbons are well known. Because naphtha polyform distillates have octane numbers of the same order as those of thermal polymer, the CFR-ASTM, CFR-Research and CFR-Road octanes of both types of gasolines were secured for comparison. This comparison is presented in Table 4, and it should be noted that there is very little difference in the general characteristics and lead susceptibility of these distillates. This table indicates that the lead susceptibility is possibly slightly better for the polyform distillate.



INSPECTION OF BLEND COMPONENTS

	Polyform Gasoline	Straight Run Mid-Continent		A-5 Reference Fuel
		Gasoline	Naphtha	
Gravity, °A.P.I.	59.8	69.6	51.5	.....
Octane No., CFR-ASTM	76.5	60.6	36.0	40.4
Vapor Pressure, PSI	10.6	13.3	2.5	.....
Distillation, Gasoline:				
Over Point, °F	85	82	144	.....
End Point, °F	391	334	474	.....
10% at, °F	127	128	234	.....
50% at, °F	229	212	328	.....
90% at, °F	351	305	420	.....
Recovery	96	94	99	.....

FIGURE 12

Blending Value of 76.5 C.F.R.-A.S.T.M. Octane No. Polyform Gasoline in: (1) A-5 Reference Fuel; (2) 51.5° A.P.I. Mid-Continent Naphtha, and (3) 69.6° A.P.I. Straight Run Mid-Continent Gasoline.

Blending Value:

Typical blending values of gasoline from these processes is illustrated by Figure 12 showing the blending value of a 76.5-octane number of polyformed distillate in blends with A-5 reference fuel and with a 69.6° API straight run Mid-Continent gasoline and a 51.5° API Mid-Continent naphtha.

The blending value of these distillates with cracked distillates varies with the octane number of the cracked distillates and the proportions of the blends.

TABLE No. 4

Comparison of Octane Numbers, Lead Susceptibility, and Blending Values of Naphtha Polyform Gasoline and Distillate From Thermal Polymerization of Propanes and Butanes

Makeup of Blend: Volume Percent											
Polyform gasoline	100	....	....	10	0	25	0	50	0	75	0
Thermal polymerization gasoline	....	100	....	0	10	0	25	0	50	0	75
Mid-Continent straight-run gasoline	....	....	100	90	90	75	75	50	50	25	25
Octane No., CFR-ASTM, Clear	76.9	78.1	56.3	58.4	59.9	63.6	63.7	69.5	69.9	73.7	75.0
+1 cc. TEL/gal	81.3	80.4	67.0	68.7	68.3	72.5	71.3	76.6	75.4	79.9	78.8
+3 cc. TEL/gal	83.7	83.3	76.2	77.9	77.6	79.8	79.1	81.8	81.2	83.1	82.2
Octane No., CFR-Research, Clear	87.1	88.4	....	61.1	60.9	64.7	66.7	74.0	74.0	81.4	81.6
+1 cc. TEL/gal	92.1	92.4	66.3	70.4	70.4	74.0	75.3	80.8	81.5	88.6	87.5
+3 cc. TEL/gal	95.0	95.3	76.3	80.0	78.4	82.4	82.0	87.1	87.0	91.8	91.4
Road Rating, 1940 Plymouth, Clear	81.0	83.5	56.5	58.5	58.5	60.5	61.0	67.0	69.5	75.5	79.5
+1 cc. TEL/gal	86.5	85.5	66.0	67.0	67.0	70.5	69.5	74.5	75.0	82.5	83.0
+3 cc. TEL/gal	90.0	88.0	76.0	79.5	76.5	81.5	78.5	84.5	81.5	87.5	86.5
Gravity, °API	61.5	62.9	64.9	....	....	....	....	....	....	....	....
Reid vapor pressures, 100 °F., PSI	10.1	10.0	8.2	....	....	....	....	....	....	....	....
Color, Saybolt	+18	+25	+30	....	....	....	....	....	....	....	....
Sulfur, L, Percent	0.02	0.12	0.01	....	....	....	....	....	....	....	....
Acid heat, °F	95	85	3	....	....	....	....	....	....	....	....
Aniline point, °F	86	99	137	....	....	....	....	....	....	....	....
Distillation:											
Over point, °F	88	94	95	....	....	....	....	....	....	....	....
End point, °F	378	437	358	....	....	....	....	....	....	....	....
10% at, °F	119	122	147	....	....	....	....	....	....	....	....
50%	197	169	226	....	....	....	....	....	....	....	....
90%	328	376	311	....	....	....	....	....	....	....	....
Recovery, percent	97.5	98.5	97.5	....	....	....	....	....	....	....	....

TABLE 5

Inspections of Clay Treated Naphtha Gas Reversion Gasoline Before and After Caustic Washing and Copper Sweetening

	To Caustic Washer	To Perco Liquid Copper Treater	From Perco Liquid Copper Treater
API Gravity	58.5	58.7	59.0
Reid vapor pressure, lbs.	7.3	7.6	7.7
Color	+30	+30	+ 30
ASTM distillation (at 760 mm):			
Initial B.P.	100	100	100
5% Recovered	132	132	130
10%	142	140	140
20%	160	158	158
30%	178	176	178
40%	196	196	196
50%	216	216	216
60%	246	242	242
70%	272	272	268
80%	306	308	304
90%	356	356	356
E.P.	410	414	414
Percent recovered	98	98	98
Percent residue	1	1	1
Percent loss	1	1	1
Percent evaporated at 212 °F.	49.5	49.5	49.5
Octane number (CFR-ASTM)	72.7	72.8	72.9
+1 cc TEL	78.1	78.2	78.1
Copper dish gum (Atlantic Hood) mg.*	10	11	12
Evaporation time	2 hr. 55 min.	2 hr. 50 min.	2 hr. 50 min.
Induction period*	5 hr. 15 min.	4 hr. 50 min.	10 hr. 0 min.
Lamp sulfur %	.038	.035	.035
Hydrogen sulfide	Trace	Nil	Nil

Note: * Tests as shown on new clay in towers. Tests after approximately 2,000 bbl./ton through clay show copper dish gun approximately 50 milligrams, and 5-6 hour induction period after copper sweetening.

In blends with low-octane cracked distillates up to 66 CFR-ASTM octane number the polyform gasoline shows a positive blending value. In blends of higher-octane cracked distillates the blending value of the polyformed distillate is approximately equal to its octane number. Figure 13 shows blends of a straight-run gasoline, a cracked gasoline, and a naphtha polyformed gasoline with inspections as indicated in the figure.

The CFR-ASTM and CFR-Research octane numbers of blends in any desired proportions of the three components can be read directly from the charts. Results are shown for clear octane numbers and with 1.5 cc tetraethyl lead per gallon.

Commercial Operations

Gas reversion has been in full-scale operation in the Phillips Petroleum Company refineries for several years and 6 units are in regular operation, representing a total charging capacity of 26,000 barrels per day consisting of one half liquefied gas and one half reversion stocks. Units are readily adjusted for variations in quality or type of charge stocks and can be operated over wide ranges of throughputs. These units operate on approximately 2000-hour cycles and have a stream-time efficiency in excess of 95 percent. All equipment used in these plants is of a commer-

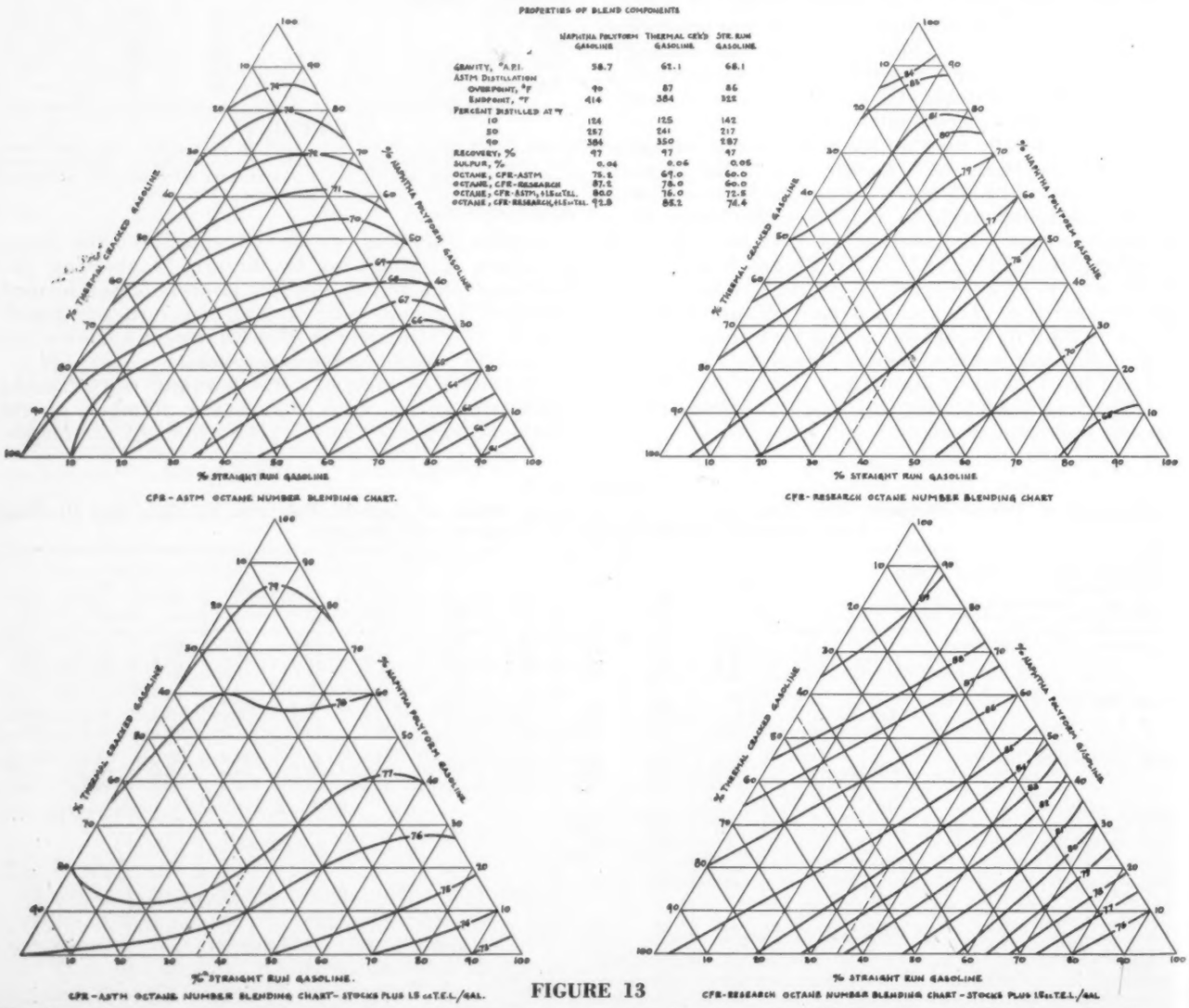


FIGURE 13

Blending Charts for Straight-Run Gasoline and Thermal-Cracked Gasoline from Gas Oil Cracking with Polyform Gasoline.

TABLE 6
Operating Utilities Based on Commercial Operations

OPERATION	1	2
Charge:		
Naphtha, B/D	1,200	4,000
Outside gas, B/D	1,500	.....
Total, B/D	2,700	4,000
Temperatures, °F.:		
Charge to furnace	530	475
Furnace outlet	1,015	1,070
Pressures, Lbs./Sq. In.:		
Charge to furnace	2,700	1,250
Furnace outlet	1,900	1,000
Fractionating system	300–400	350–370
Utilities:		
Per barrel naphtha charged:		
Electric power, KWH	7.50	1.03
Steam, lbs.	2.0	57.6
Fuel, barrels	0.176	0.072
Water (25 °F. rise), gallons	1,680	1,940
Clay, lbs.	.....	0.52
Labor, men per shift	2	3

cial nature. Operation, cleanout, and maintenance expenses are comparable with commercial reforming units.

The naphtha polyform process has been in commercial operation for over 40 years in the various refineries of Gulf Oil Corporation. In four installations a total charge of 12,000 barrels per day of naphtha, propane, and butanes are processed. These units operate 2000 to 2500 hours between clean-outs. Under construction at present are one 4000-barrel-

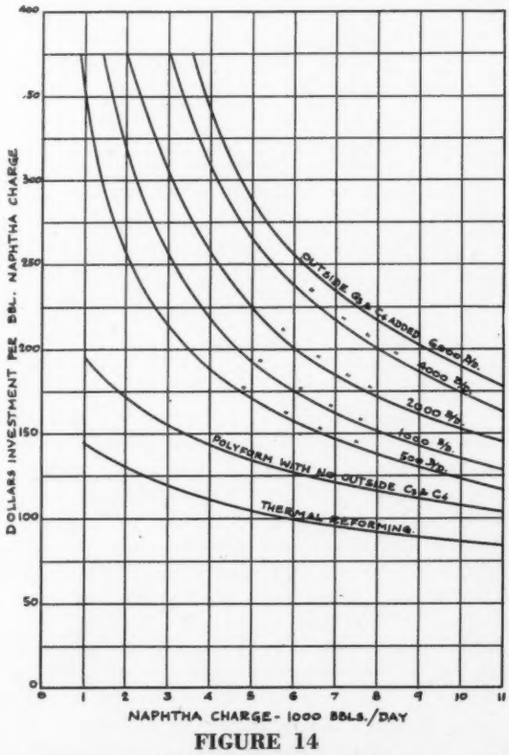

DOLLARS INVESTMENT PER BBL. NAPHTHA CHARGE
NAPHTHA CHARGE - 1000 BBLS./DAY
OUTSIDE C3 & C4 ADDED - 6000 B/D.
4000 B/D.
2000 B/D.
1000 B/D.
500 B/D.
POLYFORM WITH NO OUTSIDE C3 & C4
THERMAL REFORMING

FIGURE 14
Unit Investment Costs of Naphtha Polyform and Gas Reversion Plants.

per-day unit for Gulf Oil Corporation and one unit for a Gulf Coast refiner by The Lummus Company. This latter unit is designed to charge 9000 barrels per day naphtha and 4000 barrels per day outside propanes and butanes. Total charging capacity of naphtha-gas conversion units operating and under construction, amounts to 55,000 barrels per day. Typical flow sheets of reversion and of naphtha polyforming operations are shown in Figures 5, 6 and 7. These flows are more detailed than the fundamental diagrams given in Figures 3 and 4, and are included here for reference purposes.

Yield-octane relationships, including susceptibility to tetraethyl lead additions, from reversion operations on straight-run gasoline are given in Figure 8. The curves presented are based on charging an equal

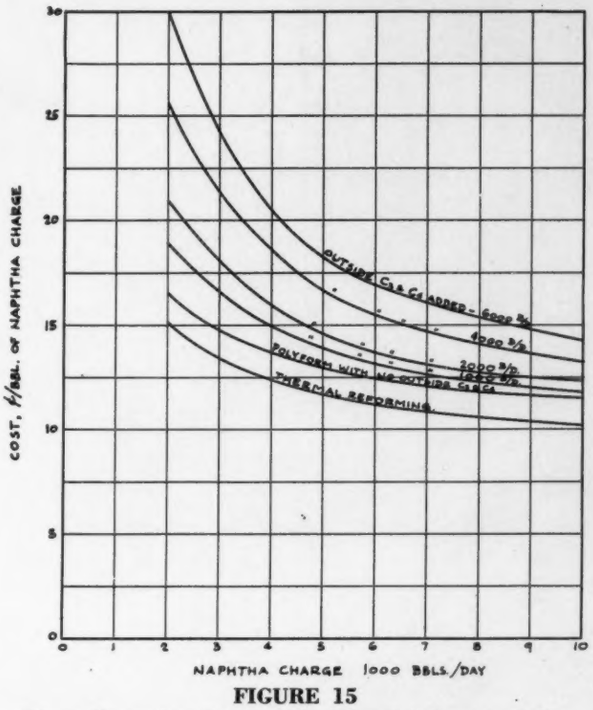
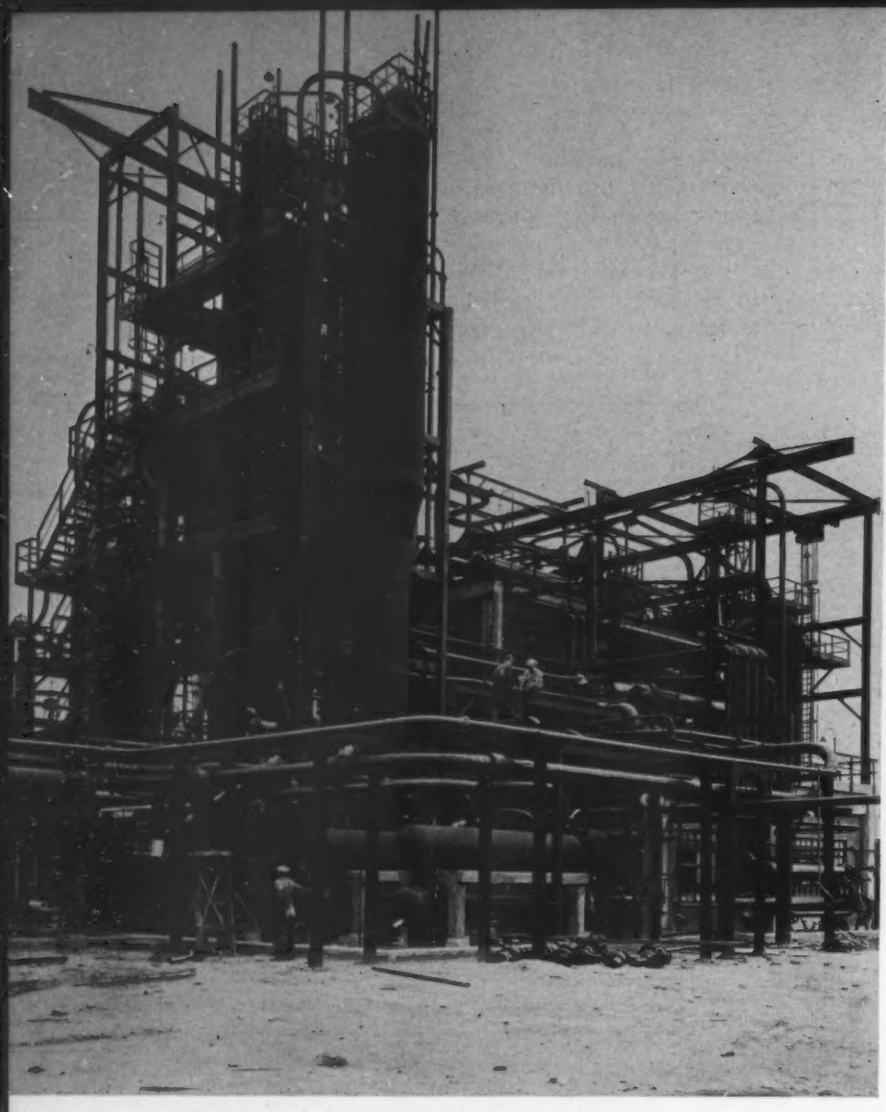

COST, ¢/BBL. OF NAPHTHA CHARGE
NAPHTHA CHARGE 1000 BBLS./DAY
OUTSIDE C3 & C4 ADDED - 6000 B/D.
4000 B/D.
2000 B/D.
1000 B/D.
POLYFORM WITH NO OUTSIDE C3 & C4
THERMAL REFORMING

FIGURE 15
Direct Operating Costs of Naphtha Polyform and Gas Reversion Units.

volume of liquefied gas for each volume of naphtha charged, and yields are expressed as a percentage of naphtha charge. Inspection of charge and yield products from these operations is shown in Table 1. It should be noted that the C_3 and C_4 content of the outside gas charge varies from 72 to 96 percent. Gasoline yields of from 120 to 135 percent and ASTM octanes of from 75.5 to 67.3 are shown. These inspections are taken from full-scale commercial operations under normal operating conditions and have been adjusted to equal charge volumes in order that direct comparison of yield-octane relationships may be made. Gasoline inspections shown are on plant-treated, copper-sweetened material. The reversion charge stock is a straight-run gasoline from Gray and Hutchinson counties, Texas, crude. Figure 8 also shows yield-octane relations for conventional thermal reforming, and for reforming plus thermal polymerization of produced gases as a reference. Similar operations on naphthas of different boiling ranges have been conducted with comparable results.

Yield and octane data from polyform operations on different stocks are shown in Figures 9, 10 and 11, Tables 2 and 2-A. Figure 9 compares yield and octane when converting a 57.9 A.P.I. gravity West Texas straight-run gasoline by thermal reforming and polyforming.

Figure 10 is a similar relationship based on a more complete series of polyforming runs on naphtha from Eastern Venezuela crude having distillations as in-



Naphtha Polyform Unit, Gulf Oil Corporation, Cincinnati, Ohio.

dicated in Table 3. The three naphthas are a 5 percent, a 10 percent, and a 15 percent fraction of the crude. The curves show the CFR-ASTM, CFR-Research, and CFR-1937 Uniontown Road octane numbers of the polyform distillates, clear, and with 1 cc. and with 3 cc. tetraethyl lead per gallon. Table 2 gives complete operating data and charge and product inspections from polyforming separately these naphthas to approximately 76 CFR-ASTM octane number. The yield of the 76-octane distillate is highest from the 15 percent naphtha with the lowest boiling range and decreases as the boiling range of the naphtha is increased. Although the octane numbers of the polyform distillates are approximately the same, the distillation characteristics are quite different. The distillate from the heaviest naphtha has a higher boiling range than the distillate from the lower-boiling naphthas. These data show very little difference in the appreciation from ASTM to Road and Research octanes of the different boiling-range distillates having the same original octane number.

By suitable variation of operating conditions, the polyform process makes it possible to produce a distillate containing a high aromatic content, even as much as approximately 40 percent.

Additional data in this table cover two operations, 5 and 6, on naphtha polyform units with outside gas charge. The variation in yields and in octane number of the products from these two runs are explained by difference in composition and quantity of C_3 and C_4 converted. Yield analysis for these two operations showing estimated source of total gasoline is given in Table 2-A.

Economics

The commercial application of any new process, regardless of improved results obtained, must be justified on an economic basis. In evaluating the economics of these processes, the trend to higher-octane motor fuels and the conservation of petroleum are important factors.

Gas-Naphtha Conversion offers improvements in yield and quality over those now being obtained from equivalent volumes of charge, therefore, the economics of this new application are of interest.

While there are numerous variables to be considered in any specific case, preliminary studies may be informative. With this in mind two curves are presented from which the approximate investment and operating cost of a commercial unit may be evolved.

Figure 14 shows investment costs for units of varying naphtha-gas charge capacities based on a gas composition containing approximately equal liquid volumes of propanes and butanes.

Figure 15 shows direct operating costs for varying naphtha-gas charge capacities.

The following assumptions have been used in preparing the curves:

Material specifications are based on processing non-corrosive stocks and representing construction costs based on labor rates prevailing in the Mid-Continent area.

Utility Costs Basis—Fuel per barrel	$0.60
Steam per 1000 pounds	0.25
Electric power per K. W. Hr.	0.005
Cooling water per 1000 gallons	0.015
Labor per man hour	1.00

An average figure for maintenance, cleaning, inspection, and repairs based on existing commercial operations has been included in the data from which Figure 15 was plotted. Table 6 presents utilities consumption for two commercial Polyform and Gas Reversion Units.

To illustrate the use of Figures 14 and 15, a plant processing 4000 barrels per day of naphtha and 2000 barrels per day of outside propanes and butanes will cost erected $257.00 per barrel of naphtha charged, or $1,028,000, and the direct operating cost will be $0.16 per barrel of naphtha charged or $640.00 per day.

Although difficult to evaluate, a Polyform or Gas Reversion plant raises the upper octane limit of the overall gasoline production and also improves the road performance.

Current realizations from naphtha gas reversion and naphtha polyform units show that the payout period on the investment for these processes is from 1 to 2 years due to increased gasoline yield and saving in tetraethyl lead. This economic picture, plus the fact that either of these operations are carried out in a single unit makes these processes attractive to the refining industry for the production of high yields of higher-level-octane motor fuels.

The Emulsion Deoiling Process

A. H. SCHUTTE
The Lummus Company

UNLIKE most refining processes, the separation of oil from crystalline waxes by conventional sweating has not been radically changed in the past years, and has been practically without competition in its field. The work of many investigators has increased the efficiency of sweating by extending knowledge of the factors involved and by improving the control methods. The equipment has been improved by mechanical refinements, but the method of separation has remained the same. Sweating is still a batch fractional melting, carried out on long time-cycles, thermally inefficient and relatively difficult to control.

A new process has now been developed, based on a novel mechanism of wax-oil separation. While the application of this principle permits the separation of any clean oil-wax mixture, commercial development of the process has thus far been confined to the deoiling of sweater stocks. This has progressed from a pilot-plant operation on a wide variety of stocks, to commercial installations of 400 and 700 barrels daily charging capacity. It offers the advantages of continuous operation under automatic control, low operating cost, and low plant cost. It is the purpose of this paper to present this process, describe its theory, the equipment employed, and the results obtained.

THIS paper has presented a new process for deoiling crystalline waxes, and summarized the pilot-plant and commercial operations. The process utilizes water emulsions to effect continuous wax-oil separations. No expensive solvents or solvent-recovery equipment is required. The processing time is a matter of minutes, rather than of days, and therefore automatic control is immediately effective. The plant cost and operating cost are low and only exhaust steam is required for heating. The method may be applied to the complete processing of slack wax to semi-refined grades; or may be used as an adjunct to existing sweating equipment.

This paper was presented before the Division of Refining at the twenty-first Annual Meeting of The American Petroleum Institute, Chicago, November 11-15, 1940.

Theory of the Process

If an oily crystalline wax stock is cooled to a temperature below its melting point, the wax solidifies in well-defined crystals, but the system is not freely separable because the wax crystals impede the flow of the oil, and because the oil adheres to the crystals. An attempt to filter the material results in very imperfect separations and difficulty with plugging of the filter medium. If, however, the oily wax is emulsified in a non-viscous, non-solvent liquid, such as water, and cooled to precipitate the desired wax, with the process so controlled that the water is the continuous phase of the emulsion, then the droplets of oil and the wax crystals are separated by water, and a freely filtering substance is obtained. In practice the cooling and emulsification usually are carried out in the same zone by the addition of the non-solvent liquid at a suitable temperature. The resulting material, which has the appearance of whipped cream, may be subjected to any kind of a liquid-solid separation, such as filtration or settling. The cake deposited on filtration, when the water and oil have been removed, is finely crystalline, porous, and may be readily washed with large volumes of water. A further fractional separation may be obtained by varying the temperature of subsequent water washes. It has been found that one of the most efficient methods of separating these emulsions, is to charge them to a filtering-type basket centrifugal, suitably jacketed for temperature control and equipped with washing nozzles. When washes are used at temperatures considerably higher than the temperature of the charge emulsion, a partial shrinkage of the cake results in a squeezing action which aids the removal of the last traces of oil. When treated in this way, the cake still retains its porosity, however, and allows a free passage of the wash liquid.

It will be noted that the process has the unique features of employing non-solvent liquids, rather than solvent liquids, and of utilizing emulsions, which up to now have been considered as undesirable nuisances by the petroleum refiner. In addition to the above mentioned benefits of emulsification, there is apparently an improvement in crystal structure, due to the fact that the wax is solidified from a thin interfacial film, rather than from the main body of a liquid. This effect has been noted in the commercial deoiling of waxes containing high end-point constituents, which would render them virtually unsweatable. In this case the film crstallization apparently decreases the effect of the naturally occurring inhibitors.

Description of Processing Equipment

The equipment for a single-stage emulsion deoiling is shown on the flow sheet, Figure 1. The oily wax to be processed is introduced by Pump G-1 into the suction of the emulsifier G-2. The volumetric capacity of the emulsifier is 10 to 20 times the quantity of

wax charged, and this excess material is by-passed back to the emulsifier suction. A small amount of compressed air is introduced with the wax. The temperature of the net emulsion is controlled by an automatic instrument operating on the water introduced to the emulsifier. The proportions of water and wax charge, since the characteristics of the emulsion cause a self-propulsion of the cake. Due to the presence of emulsified water in the charge, the density of the material at the feed point is considerably greater than the density of the deposited cake. The internal pressure, acting on any particle of dry cake, is consider-

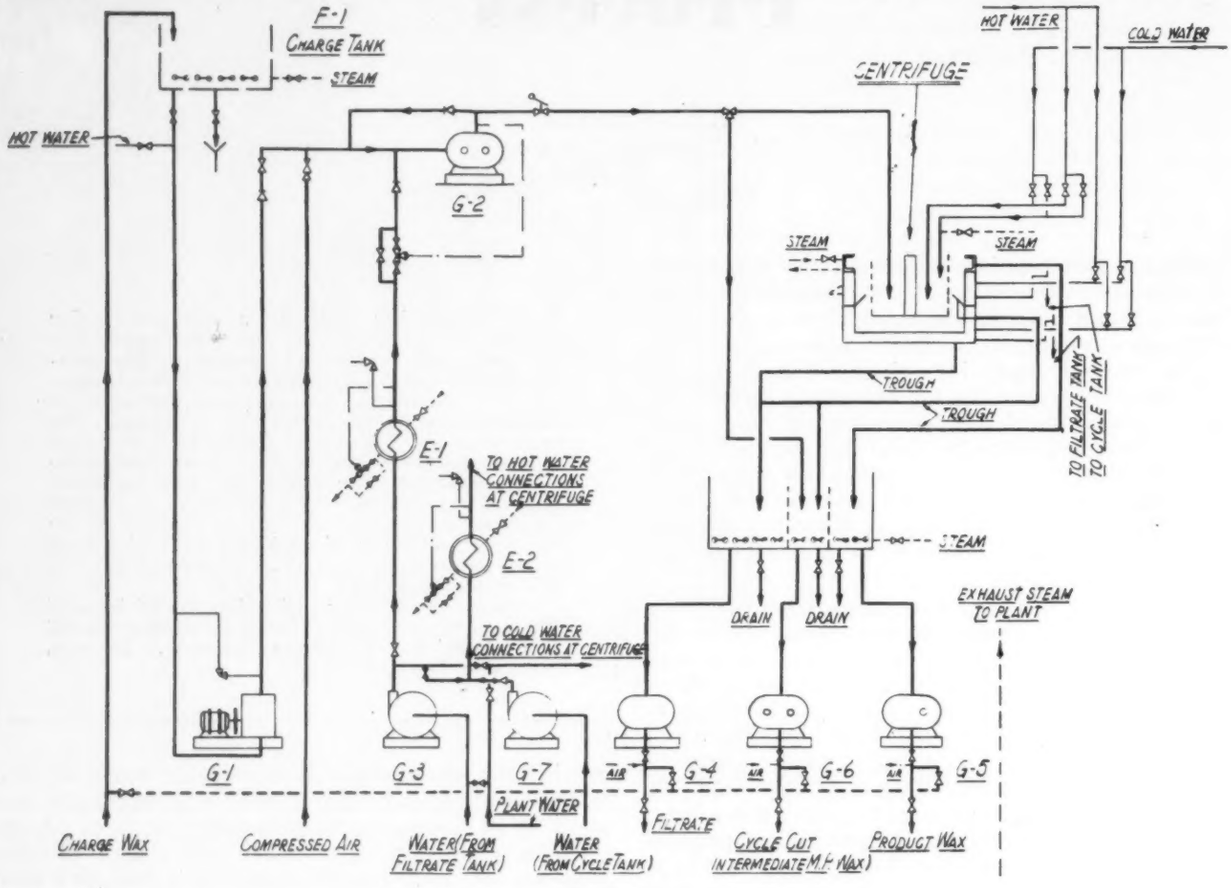


FIGURE 1
Emulsion Deoiling Process

are adjusted by controlling the temperature of the water in Exchanger E-1. The net emulsion is charged to a perforate-wall centrifugal lined with a filter medium. The unsolidified portion of the original waxy charge and the emulsified water are thrown out and collected in the lower portion of the jacketed housing surrounding the rotor. The deposited cake travels continuously up the wall of the machine as an annular mass and is discharged over the top lip of the basket into a steam-jacketed melting ring, from which it flows to one compartment of Tank F-2. The cake may be washed during its progress up the wall of the machine at several levels by water at controlled temperatures. The upper wash material may be withdrawn separately and used as a recycle stock if desired.

The operation of this type of centrifugal may be more clearly seen by reference to the cross sectional cut given in Figure 2. The machine differs from a conventional basket-type filtering centrifugal in that the curb housing is divided into three jacketed sections. The top section is steam-heated for cake melting and the other two sections allow control of the temperatures in the primary filtration and washing zones. There is no mechanical means required to propel the cake upward and cause its continuous disably less than that acting on a particle of feed slurry. This results in a net upward force in the cake which displaces it as an annular mass upwards along the wall of the rotor. Studies of this action have been made by introducing feed slurries containing insoluble dyes. Cakes formed in this way were then cut into strips and removed. The line of demarcation between the undyed original cake and that deposited from the dye-containing subsequent charge is roughly a half-parabola having its axis along the surface of the filter medium.

A view of the pilot deoiling unit is shown in Figure 4. This uses a 10-inch centrifugal which was remodeled from a standard small laboratory machine. The charging capacity of the unit is 10 gallons per hour.

The first commercial plant was built in an automobile box-car, and so designed that the car can be placed on a refinery siding, requiring only the connecting of electrical power and exhaust steam, water, charge, and product lines. This plant was designed for 400 barrels per day of slack wax and has exceeded this capacity in service. A general view is given in Figure 5. Figure 6 shows the charge pump, emulsifier, and water-heating exchangers. Figure 7 is a view taken inside of the car looking toward the

TABLE 1
Typical Data—Pilot Emulsion Deoiling Unit

CHARGE STOCK SOURCE	Charge		PRODUCT WAX		Yield Volume Percent on Charge	Number of Deoiling Steps
	Melting Point	Percent Oil*	Melting Point	Percent Oil*		
1. East Texas Pressed Slack Wax	107	26	122.5	1.7	40.2	3
2. East Texas Pressed Slack Wax	107	26	129.5	0.5	25.8	5
3. East Texas Pressed Slack Wax	112.5	30	122.5	10.7	57.5	1
4. M. C. Cold Pressed Slack	96	(too high)	115.5	11.8	13.3	1
5. M. C. Cold Pressed Slack	96	(too high)	105	34	36.0	1
6. Penn. Solvent Dewaxing Slack	122.5	(10.0)	127	(.07)	62.0	1
7. Penn. Solvent Dewaxing Slack	122.5	(10.0)	130	(0.2)	41.5	1
8. Penn. Slack Wax	115	(20)	122.5	(5.5)	72	1
9. M. C. Pressed Slack Wax	108	35.6	115	16	71	1
10. M. C. Pressed Slack Wax	108	35.6	119.5	5.5	43.8	1
11. M. C. Pressed Slack Wax	108	51.4	118	26.6	51.4	1
12. Far Eastern Wax Stock No. 1	99	32.6	107	13.6	34	1
13. Far Eastern Wax Stock No. 1	99	32.6	109	7.3	24.8	2
14. Far Eastern Wax Stock No. 2	116	11.8	118.5	7.1	86.5	1
15. Far Eastern Wax Stock No. 3	135.1	3.9	138.5	1.2	72.2	1
16. M. C. Pressed Slack Wax	108.5	36	117.6	16.5	64.1	1
17. East Texas Pressed Slack Wax	105.6	42.2	115.8	20.3	60.2	1
18. California Solvent Dewaxing Slack	121.6	25.1	128.7	2.0	59.0	1

* Oil contents run by modified ASTM procedure using special light cloth, correlated with solvent method. Oil contents enclosed by parentheses run by ASTM method D-306-29T.

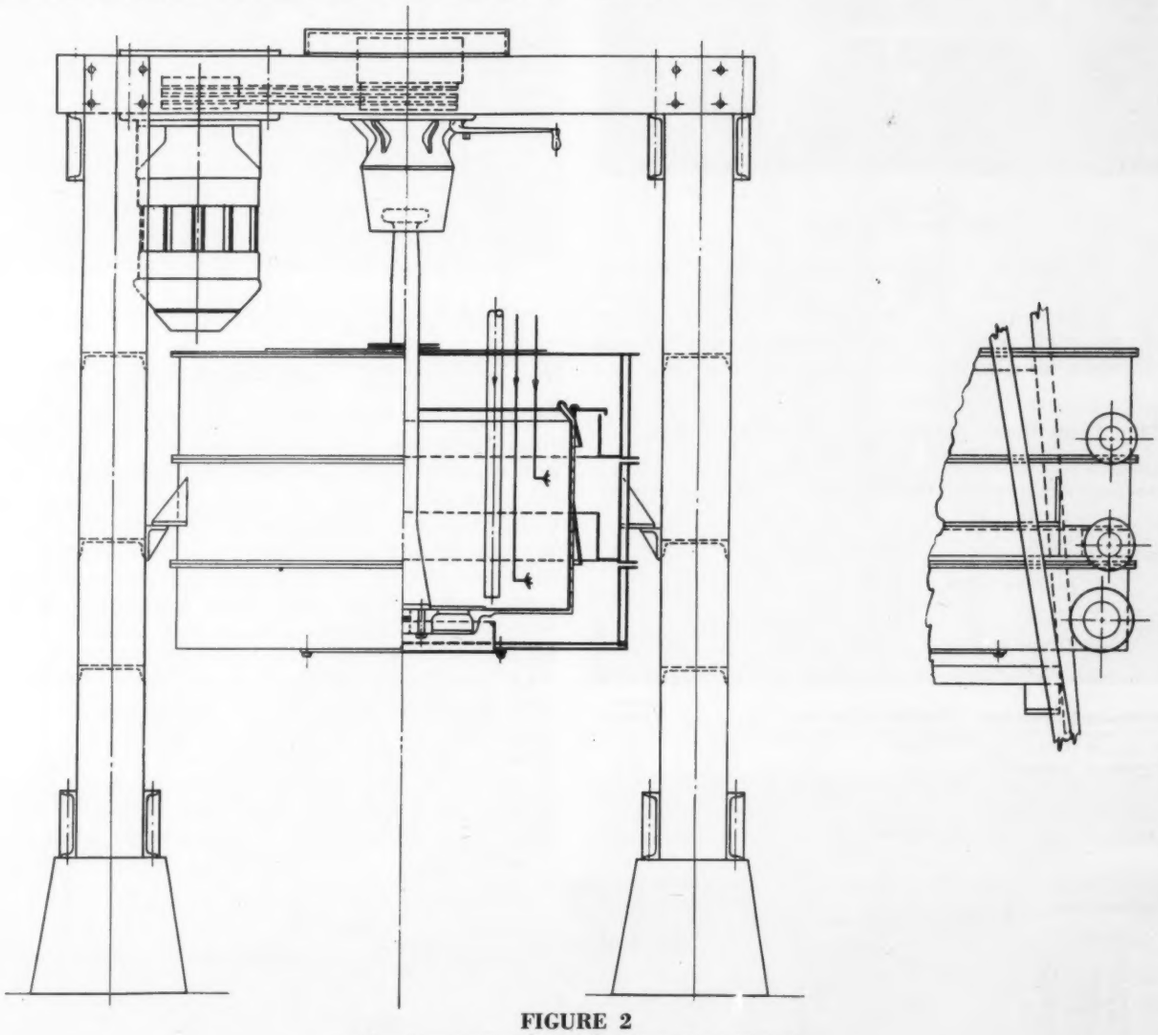


FIGURE 2
Continuous Emulsion Deoiling Centrifugal

48-inch centrifugal, and Figure 8 is a close-up of the centrifugal showing the emulsion charge line, the wash lines, and the troughs which carry off the filtrate, cycle, and overhead cake. This plant has been operating since early in the spring in the Pennsylvania field, producing marketable wax from slack wax obtained by solvent dewaxing. The refinery has no sweating equipment, and this box-car plant, plus clay percolation equipment, constitutes the entire wax plant.

A view of a 60-inch suspended centrifugal in a permanent 700-barrel-per-day installation is shown in Figure 9. The photograph shows the wash-and-jacket-water control manifold and part of the instrument board. This unit operates on a Mid-Continent slack wax from plate and frame presses.

Discussion of Results

Pilot-Plant Operations:

Typical data for pilot-plant-emulsion-deoiling op-

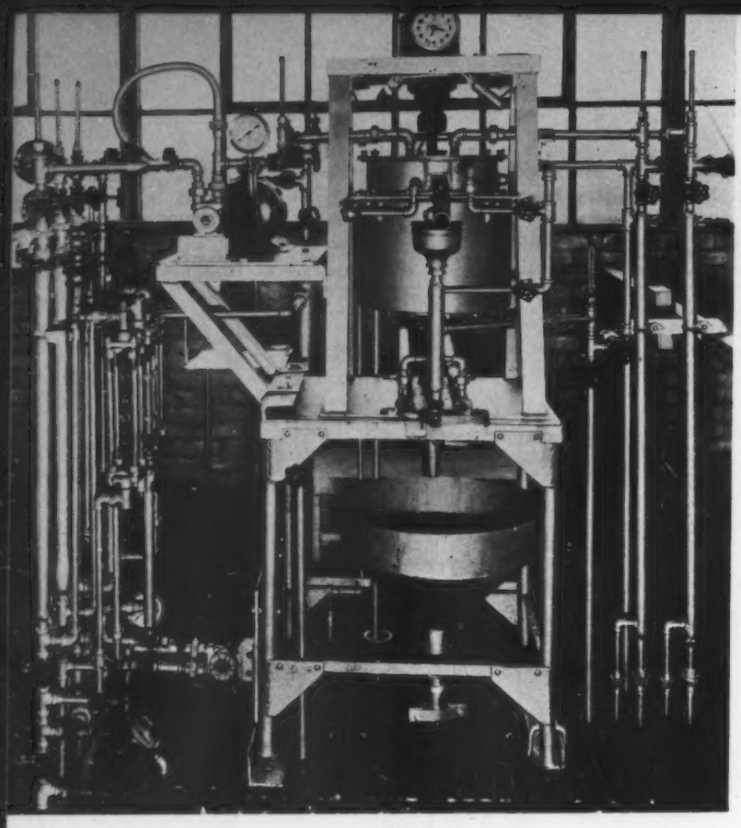


FIGURE 4
Pilot Deoiling Unit

erations on various stocks are presented in Table 1. These stocks include three East Texas pressed slack waxes, Mid-Continent cold-pressed slack, Pennsylvania and California solvent-dewaxing slacks, and Far Eastern wax stocks. In most of these runs hot

TABLE 2
Pilot Plant Data—Single-Stage Emulsion Deoiling Followed by Sweating

Emulsion Deoiling Operation—Once Through	E. Texas Pressed Slack Wax
Charge:	
M.P., °F	112.5
Percent Oil	29.8
Cake:	
Yield, Volume Percent on Slack	57.5
M.P., °F	122.5
Percent Oil	10.7
Filtrate:	
Yield, Volume Percent on Slack	42.5
M.P., °F	93

Single Sweating Operation	Cut No. 1	Cut No.2	Cut No. 3	Semi-Refined
Vol. Percent on Deoiled Cake	20.6	2.1	38.3	39.0
Vol. Percent on Original Slack	11.9	1.2	22.0	22.4
M.P., °F	95	115.5	123.8	132.0
Percent Oil	....	15.6	0.8	0.14
Tensile Strength, Lbs./sq. in.	....	....	....	412

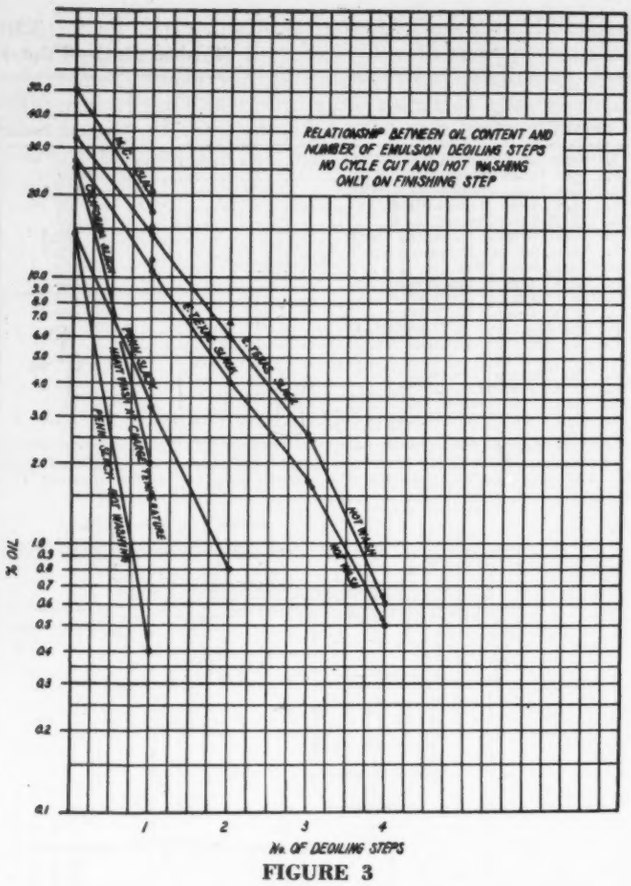

RELATIONSHIP BETWEEN OIL CONTENT AND NUMBER OF EMULSION DEOILING STEPS NO CYCLE CUT AND HOT WASHING ONLY ON FINISHING STEP
% OIL
No. OF DEOILING STEPS

FIGURE 3

washing was used only on the final finishing step, since the pilot unit has no side cut to segregate the hot wash filtrate from the primary filtrate or foots oil. The degree of oil separation obtained on the California solvent-dewaxing slack in a single-step process is much greater than that shown for the other stocks. This is a reflection of the improvements made in the pilot-plant equipment in the last few months. Figure 3 is a plot which shows the relationship between the oil content of the charge wax and the oil content of the cake obtained from each deoiling step when hot washing is used on only the final operation. It will be noted that there is a definite and constant relationship between the oil contents remaining after each pass. With the exception of the California slack wax, this relationship indicates the equilibrium obtained in the original emul-

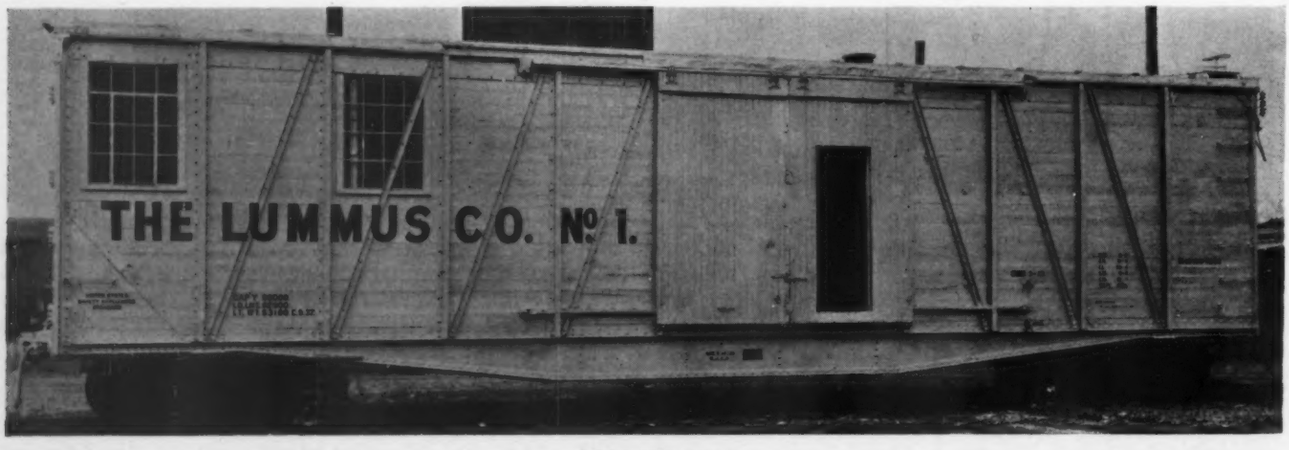


FIGURE 5

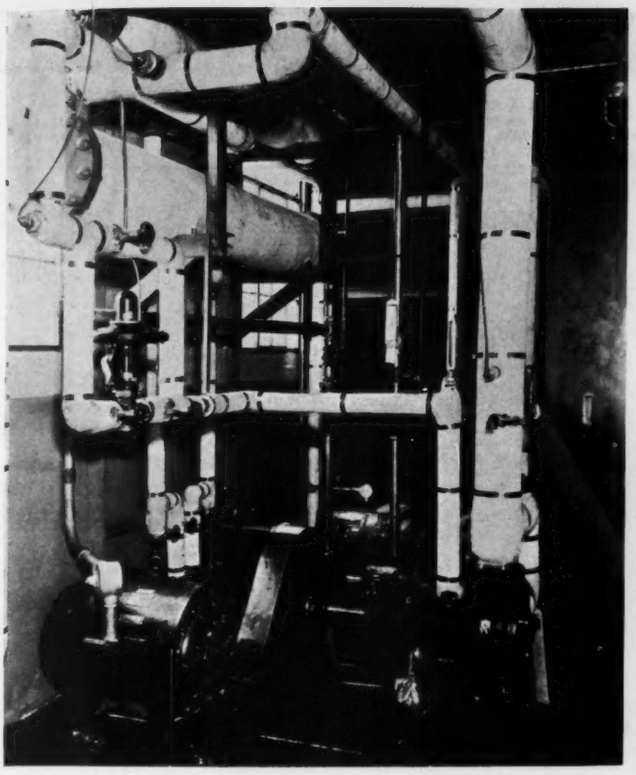


FIGURE 6
Charge Pump, Emulsifier and Water Heating Exchangers

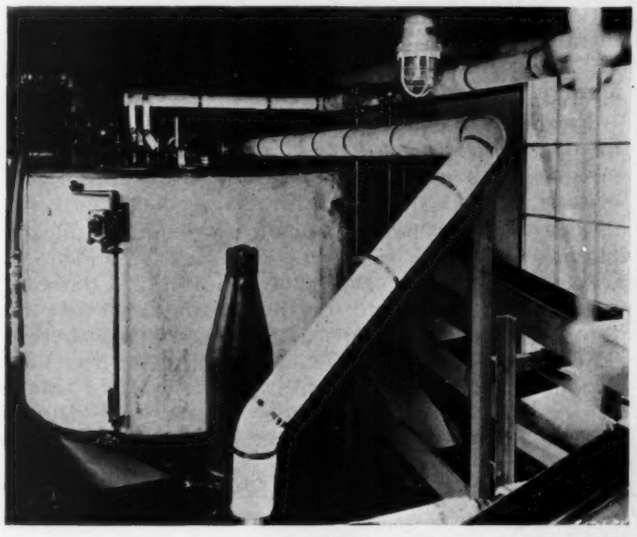


FIGURE 8
48-Inch Centrifuge Deoiling Unit

sion charged to the centrifugal. In the case of the California stock, several improvements have been made in the emulsification system and a heavy, well distributed wash was employed at the charge temperature. The factors influencing the degree of oil separation are as follows:

1. The crude source from which the slack wax is obtained. This effect will be noted by the difference in the slopes of the lines for well fractionated, sweatable, slack wax from various crude sources.
2. The percentage of oil in the original charge.
3. The degree of fractionation obtained in the distillation unit which produced the original wax distillate. As pointed out previously, this effect is less important in emulsion deoiling than in conventional sweating. Poorly fractionated slack wax usually gives no trouble with operation in emulsion deoiling, but the structure of the final product wax is apt to be poor. The curves of Figure 3 are given to show the relationship between the oil content of the charge and that of the solid phase in the original emulsion and they do not represent the ultimate separation possible by washing and by the segregation of the hot wash filtrate.

Table 2 gives the result obtained by a single-stage emulsion deoiling of an East Texas pressed slack wax, followed by a single laboratory sweating. The original slack charged to the emulsion-deoiling operation had a melting point of 112.5° F., and contained 29.8 percent oil. A yield of 57.5 percent of cake was

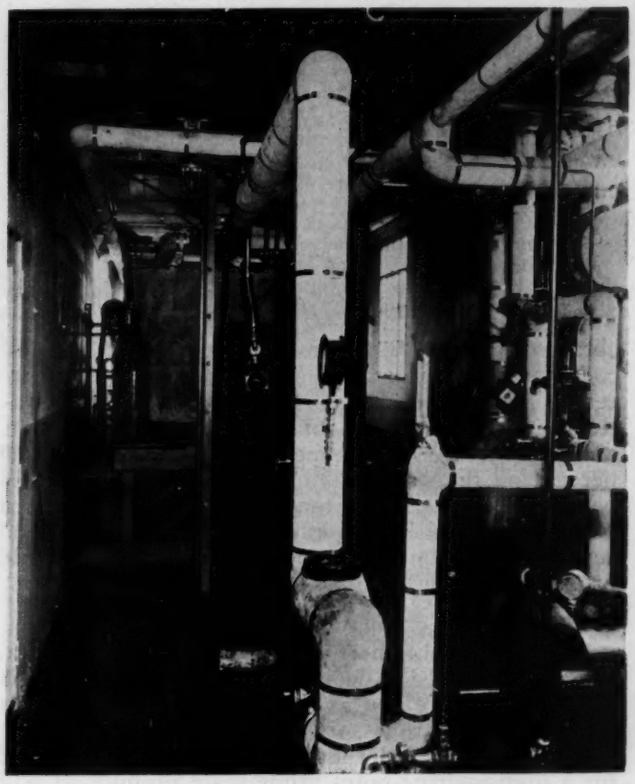


FIGURE 7
View Inside Box Car Toward Centrifuge

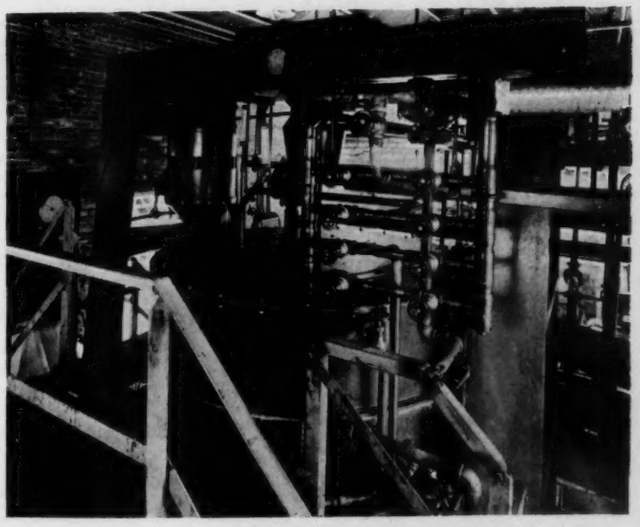


FIGURE 9
Deoiling Unit Showing 60-Inch Suspended Centrifuge

FIGURE 3
Plant Data—Emulsion Deoiling Operations—Commercial Operation 48-Inch Centrifugal

	A B-A Slack Wax From 125 Vis. Dist.	B Cylce From A	C B-A Slack Wax from 50% 80 Vis. —50% 250 Vis. Dist.	D Accumulated Filtrate From Other Operations	E Cake From D	F B-A Slack From 155 Vis. Dist.
Charge Stock:						
M.P., ASTM	125–127	124	118.6	114.4	123	120
Percent Oil, Press Method	4–11	5	14.3	21	1.3	6
E.P., 10 mm	590–615	.....	680 to 700+	.....	.....	.....
Cake:						
Volume Percent on Charge	52	45.2	47.3	48	52	43
Volume Percent Slack Wax	52	8.6	47.3	.....	.....	.....
M.P., ASTM	130–131	129.1	128.6	123	129	130
Percent Oil, Press Method	0.4–0.7	0.4	0.4	1.3	0	0
Filtrate:						
Volume Percent on Charge	29	54.8	52.7	52	.....	.....
Volume on Slack Wax	29	10.4	52.7	.....	.....	.....
M.P., ASTM	118	118.8	110	.....	.....	.....
Percent Oil, Press Method	.....	13.3	.....	106	.....	.....
Cycle:						
Volume Percent on Charge	19	.....	.....	.....	.....	.....
Volume Percent on Slack Wax	19	.....	.....	.....	.....	.....
M.P., ASTM	124	.....	.....	.....	.....	.....
Percent Oil, Press Method (A and B)	5	.....	.....	.....	.....	.....
Overall Scale Wax, Volume Percent on Slack	60.6		.....	.....	.....	.....
Overall Fitrate, Volume Percent on Slack	39.4		.....	.....	.....	.....
Charge Rate, B/D	396	495	.....	430	430	400
Lb./hr. Exhaust Steam	660 (40/bbl.)	.....	.....	.....	.....	.....
G.P.M. Water, No. Reuse	19 (69 gals./bbl.)	.....	.....	.....	.....	.....
K.W.H Power	26.5 (162. WKH/bbl.)	.....	.....	.....	.....	.....
Utility Costs:						
Cents/bbl. Slack, Steam*	1.000	.....	.....	.....	.....	.....
Cents/bbl. Slack, Water	.035	.....	.....	.....	.....	.....
Cents/bbl. Slack, Power	.81	.....	.....	.....	.....	.....
	1.845					

* Steam at 25 cents/1000 lbs., water at 0.5 cents/1000 gallons., power at 0.5 cents/K.W.H.

obtained with 122.5° F. melting point, and an oil content of 10.7 percent. This cake sweated to 22.4 percent on the original slack of 132 melting point semi-refined wax, having an oil content of 0.14 percent and over 400 tensile strength. The next cut of 22.0 percent on the slack was of 123.8 melting point, 0.8 percent oil. This shows that stocks which have been partially deoiled by the emulsion process give good separations upon subsequent sweating and yield products of high quality.

Commercial Operations

The results obtained from the commercial operation of an emulsion-deoiling plant having a 48-inch centrifugal, are given in Table 3. The charge stocks were obtained from solvent dewaxing of Pennsylvania distillates and the plant usually was operated for a high-melting-point crude scale product. It will be noted that the overall yield was 60.6 percent of 130-melting-point scale wax, containing 0.4 percent oil. The operation shown in column "C" is of interest because of the high degree of separation obtained on a charge material containing high-end-point waxes which normally would be unsweatable. The oil separation from 21 to 1.3 percent upon rerunning the filtrate, is also of interest. The operation in column "F" shows the production of a semi-refined wax in a single step from solvent dewaxing slack.

Reference to the utility data shows an economy of operation in marked contrast to conventional sweating; as evidenced by the overall utility cost of only 1.8 to 1.9 cents per barrel of charge.

The operating performance for a deoiling unit employing a 60-inch centrifugal is given in Table 4. Typical operations are shown for Mid-Continent pressed slack wax and for the rerunning of sweater foots oil to recover the scale wax contained therein. The operation on an 86-cold-test sweater foots oil producing an 80-cold-test filtrate and a 113° F.-melting-point cake, is of particular interest and demonstrates a versatility which should be of value in plant practice.

A distinguishing feature of emulsion deoiling is the compactness of the equipment, as evidenced by the installation of a 400-barrel-per-day unit in a box car. All process heat requirements are met by low-pressure exhaust steam and therefore wax production capacity is obtained without additional boiler load. The equipment may be operated at emulsion temperatures within 4° to 5° of the cooling water temperature. Refrigeration is therefore required only when the plant cooling water temperature is above approximately 80° F. Based on representative refinery utility costs, the total direct operating cost including labor is only 4 to 5 cents per barrel of charge for a single-stage operation of the type shown in Table 4. This operating cost is far lower than that usually encountered in conventional sweating. The operating cost of 10.4 cents per barrel for rerunning the foots oil shows a saving over conventional methods of recovering this wax.

TABLE 4
Plant Data—Emulsion Deoiling Operations—60-Inch Centrifugal

CHARGE	Slack Wax From M.C. Crude		Sweater Foots Oil	
Throughput, B/D	620 (750 gross)		338	
Vol. Percent Cake on Charge	68.0		14	
Charge Inspections:				
M.P., °F ASTM	106.8		86	
Percent Oil, Press Method	45+		(cold test)	
Cake Inspections:				
M.P., °F. ASTM	116.5		113	
Percent Oil, Press Method	16		26	
Filtrate Inspections:				
M.P., °F.	85		81	
Cold Test, °F.	82		80	
Cloud Test, °F.	85.8		81.5	
Percent 122 M.P. Wax, Solvent Method	14.3		10.5	
Direct Operating Cost, Cents/Bbl. Charge:				
Power	1.3 KW/bbl.	1.0	2.5 KW/bbl.	1.62
Water, 77 °F.	345 Gals./bbl.	0.17	.....	Reused
Refrigeration	.....	.....	36.5 Tons*	1.69
Labor	1 Man/Shift	3.0	1 Man/Shift	7.10
	Total.....	4.17	Total.....	10.41

* Based on reuse of water and net cooling by steam jet refrigeration. Water at ½ cent per 1000 gallons, 77 °F. Power at ½ cent per KW.

Synthetic Chemicals From Petroleum

L. ROSENSTEIN
Shell Chemical Company

THE manufacture of synthetic chemicals from petroleum and natural gas has been one of the major developments in the chemical industry during the past decade. As an example, Shell Chemical Company's production of ammonia has increased from 4,500 tons in 1931 to 27,000 tons in 1939; of solvents from 90,000 pounds to 57,000,000 pounds in the same period. A continually increasing variety of chemicals of exceptionally high purity is being made available at constantly decreasing cost, from cheap raw materials whose supply is stable, abundant and remarkably adaptable. Alcohols, ketones, and esters made from refinery gases that formerly were used only as furnace fuel now are known quite well to chemical markets. Many new products, now produced on laboratory and pilot-plant scale by Shell Development Company, in due course will join them. Among these are unsaturated alcohols and chlorides, glycerol and its derivatives, and butadiene.

The entrance of the petroleum industry into the field of synthetic chemicals has had a profound influence upon the development of synthetic gasolines; thus the development of *iso*octane was associated closely with that of secondary butyl alcohol. Other similarly close relationships may be expected as petroleum chemicals play an increasingly important part in the economics of the industry.

This paper was presented to Division of Refining, before Twenty-first Annual Meeting of the American Petroleum Institute, Chicago, November 13, 1940.

THE manufacture of synthetic chemicals from petroleum and from natural gas, closely related to it, is becoming a major American industry. Petroleum is well suited as a chemical raw material: it is cheap and abundant, and contains a wide variety of chemical types which, in themselves or after cracking to simpler compounds, may be converted to derivatives of many kinds. Several general reviews of this field recently have appeared[1,2,3,4]; the present paper will be concerned largely with developments in which Shell Chemical Company has played some part. These developments are, however, typical of the petroleum chemical industry as a whole.

At the outset a word of explanation may be in order regarding the relation of Shell Chemical Company to its associates, Shell Oil Company, Inc., and Shell Development Company. By and large it may be said that Shell Chemical Company operates on raw materials which Shell Oil Company is in a position to furnish; and it uses processes and manufactures products which have been developed in the research laboratories and pilot plants of Shell Development Company. On behalf of Shell Chemical Company, the latter carries on extensive market research concurrently with its investigations of processing, to the end that applications may be found and markets developed for present and potential chemical products, and new products may be supplied to meet the expressed needs of industry.

In the synthetic-chemical field Shell Chemical Company has been active both in the synthesis of alcohols, ketones, etc., from refinery cracked gases, and in the manufacture of ammonia and related products from natural gas and atmospheric nitrogen. Commercial operations were begun in 1930 with the production of secondary butyl alcohol from butylene at Martinez, California; and, within a year, the synthesis of ammonia at Shell Point, near Pittsburg, California. Expanding operations necessitated extension of the Martinez plant in 1933 to manufacture tertiary butyl alcohol and methyl ethyl ketone, and soon thereafter at the same location a plant was built to regenerate spent alcohol acid to make it usable in manufacturing ammonium sulfate. In 1936 a large alcohol and ketone plant was built at Dominguez, near Los Angeles; and this since has been enlarged to produce acetates and higher-boiling ketones. In the first year of commercial operation about 4500 tons of ammonia and 90,000 pounds of solvents were produced; in 1939 the corresponding figures were 27,000 tons and 57,000,000 pounds. About half of the ammonia produced is converted into ammonium sulfate; and in this connection it may be noted that means have been found to use acid sludge from petroleum refining for this conversion, without impairing the quality of the ammonium sulfate produced.

The manufacture of ammonia at Shell Point begins with the cracking of natural gas over a brick checkerwork, at an average temperature of 1100° C., yielding a gas containing 70 percent of hydrogen, the rest being unconverted methane, with small amounts of nitrous oxide, carbon monoxide, carbon dioxide, benzene, ethylene, acetylene, and naphthalene. Most of the carbon content of the natural gas is converted to the solid form; it is separated from the crude hydrogen by washing with water and by electrical precipitation. Nitrous oxide is removed from the hydrogen by passage over iron oxide; naphthalene and benzene by washing with oil; carbon dioxide by washing with water and alkali; and light hydrocarbon impurities (methane, ethylene, and acetylene) by low-temperature fractionation, in the last stage of which liquefied atmospheric nitrogen is introduced to aid in the removal of carbon monoxide by fractionation, and to form a nitrogen-hydrogen mixture in the molecular proportions of ammonia. In the synthesis plant the last traces of carbon monoxide and oxygen are removed, and the synthesis is effected under high pressure, the ammonia emerging

as a gas ready for liquefaction or conversion into ammonium sulfate.

The principal application of ammonia is agricultural. When irrigation is practised, farmers use the ammonia as a fertilizer in liquefied form, when it is carried into the soil in highly dilute solution with the water. In the form of ammonium sulfate it is used on land prior to irrigation, or on non-irrigated land. Ammonia is used also by large cities in the purification of water, in oil refineries as a neutralizing agent and corrosion preventive, and in cold-storage and ice-manufacturing equipment as a refrigerant. It is also a source of nitric acid for the manufacture of explosives, cellulose nitrate, etc.

The carbon which is left after the hydrogen has been removed from methane is processed further to meet the exacting requirements of the rubber industry. It has found wide acceptance as a soft carbon, such as is used in the compounding of rubber for hose, tubing, gaskets, and mechanical goods. That part of the carbon not suitable for this trade is made into briquettes which, because of their very low ash content and nearly zero sulfur content, have been found useful in metallurgy, more especially in steel production.

The production of alcohols, ketones, etc., from cracked petroleum gases has grown steadily in the past two decades. Thus, according to Tariff Commission reports, 37,500 gallons of *iso*propyl alcohol were made via the sulfation of propylene in 1922, 1,500,000 gallons in 1931, and 27,500,000 gallons in 1939. During this period the price fell steadily from $2.00 per gallon to 31 cents per gallon.

The process used by Shell Chemical Company for the production of alcohols from olefins consists of:

a. Production of pure hydrocarbon fraction containing only the olefin and its corresponding paraffin.
b. Absorption of the olefin content in concentrated sulfuric acid to produce the alkyl hydrogen sulfates and dialkyl sulfates.
c. Separation of the products (b) from unreacted hydrocarbons.
d. Hydrolysis of the products (b) to either alcohols or ether in dilute sulfuric-acid solution.
e. Removal of alcohols and ethers from solutions (d) by distillation.
f. Subsequent purification of alcohols and ethers by fractionation.

In this way *iso*propyl alcohol and di*iso*propyl ether are made from propylene, secondary butyl alcohol from α- and β-butylenes, and tertiary butyl alcohol from *iso*butylene.

Acetone is made from *iso*propyl alcohol, and methyl ethyl ketone from secondary butyl alcohol, by catalytic dehydrogenation and subsequent fractionation. These two alcohols also are converted to the corresponding acetates by continuous esterification processes especially developed for this purpose.

From acetone a further series of products is made: diacetone alcohol by catalytic condensation of acetone at low temperature, and subsequent fractionation; mesityl oxide by the catalytic dehydration of diacetone alcohol; and methyl *iso*butyl ketone by the catalytic hydrogenation of mesityl oxide.

Physical properties of these products, all made on commercial scale by Shell Chemical Company, are listed in Table 1.

The principal uses of the alcohols, ketones, and esters are as solvents and extractants in the manufacture of lacquers, varnishes, and allied products, synthetic resins, plastics, synthetic fibers, artificial leather, safety glass, photographic films, printing inks, cosmetics, medicinal preparations, explosives, etc., and also in the dewaxing of mineral oils and extraction of vegetable and animal materials.

The alcohols and ketones have found extensive use as base material for chemical synthesis to make products such as esters, chlorides, ethers, xanthates, substituted hydrocarbons, fruit essences, perfumes, dyestuffs, wetting agents, and synthetic resins. *Iso*propyl alcohol, because of its complete miscibility with water, is used extensively as a component of anti-freeze solutions for automobile radiators.

As a particular example of these olefin derivatives, let us consider methyl ethyl ketone—which until recently was available commercially only as a component of "light acetone oil," a by-product of the wood-distillation industry. This mixture was limited in quantity and of uncertain composition, and never found extensive in-

TABLE 1
Properties of Pure Compounds

Compound and Chemical Formula	Molecular Weight	Specific Gravity (20/4° C)	Boiling Point at 760 Mm Mercury (°C)	Melting Point (°C)	Vapor Pressure at 20° C (Millimeters of Mercury	Flash Point (Closed Cup) (°F)	Pounds Per Gallon at 20° C	Solubility with Water (Percent by Weight at 20° C)		Azeotrope With Water	
								Compound in Water	Water in Compound	Boiling Point (°C)	Percent by Weight of Compound
Ketones											
Acetone: $CH_3.CO.CH_3$	58.08	0.7898	56.1	— 95.0	186.2	5	6.59	Complete	Complete	.....	.....
Methyl ethyl ketone: $CH_3.CO_2CH_5$	72.10	0.8047	79.6	— 86.4	71.2	25	6.72	27.0	12.5	73.4	88.7
Methyl *iso*butyl ketone: $CH_3.CO.CH_2.CH(CH_3)_2$	100.16	0.8004	115.9	— 83.5	15.2	60	6.68	1.7 (25 deg)	1.9 (25 Deg.)	87.9	75.7
Meistyl oxide: $CH_3.CO.CH:C(CH_3)_2$	98.14	0.8546	129.5	— 59	8.0	83	7.13	3.1	3.1	91.8	65.2
Diacetone alcohol: $CH_3.CO.CH_2.COH(CH_3)_2$	116.16	0.9384	166 (approx.)	— 47	0.84	144 (open cup)	7.83	Complete	Complete	98.8	12.7
Esters											
*Iso*propyl acetate: $CH_3.COO.CH(CH_3)_2$	102.13	0.8719	88.6	— 73.4	....	39	7.28	2.9 (25 Deg.)	2.0 (25 Deg.)	76.6	89.4
Secondary butyl acetate: $CH_3.COO.CH(CH_3).C_2H_5$	116.16	0.8711	112.4	.....	16.2	64	7.27	....	....	87	77.5
Alcohols											
*Iso*propyl alcohol: $CH_3.CHOH.CH_3$	60.09	0.7848	82.3	— 89.5	31.5	54	6.55	Complete	Complete	80.2	87.7
Secondary butyl alcohol: $CH_3.CHOH.C_2H_5$	74.12	0.8065	99.5	—114.7	12.1	73	6.73	24.4	56.0	87.5	72.7
Tertiary butyl alcohol: $(CH_3)_3.COH$	74.12	0.7791 (26 Deg.)	82.4	25.6	57.3 (30 Deg.)	48	6.50 (26 Deg.)	Complete	Complete	79.9	88.3
Ethers											
*Iso*propyl ether: $(CH_3)_2.CH.O.CH(CH_3)_2$	102.16	0.7238	68.4	— 86.8	120.2	—6	6.04	1.0	0.5	62.2	95.5

dustrial uses. Since the introduction of synthetic methyl ethyl ketone from petroleum, a pure product of uniformly high quality, it has been consumed in increasing quantities by a variety of industries. For instance, it is an excellent solvent for nitrocellulose, with good tolerance toward the other materials that are used in lacquer manufacture, and in many of its properties it excels the esters as a lacquer solvent. It is also an exceptionally good solvent for the highly polymerized vinyl-type resins. It is used as a paint remover, an extractant in various applications, and a dewaxing agent for mineral oil. It finds extensive use in the processing of cellulose-acetate plastics, in the synthesis of rubber chemicals, and in the manufacture of rotogravure and intaglio inks.

Besides these major products, scores of others are in various stages of development in the research laboratories and pilot plants of Shell Development Company at Emeryville. Many of these are produced on semi-commercial scale; among them are several unsaturated chlorides and alcohols and their derivatives made from propylene and the butylenes via substitutive chlorination,[5] followed by hydrolysis, chlorhydrination, etc.[1,6] A number of these products, with physical properties, are listed in Table 2. The first commercially practical synthesis of glycerol[7] was an outgrowth of these developments. This is now ready for full-scale application whenever economic conditions justify.

Also in the stage of semi-commercial development is butadiene, which is of growing interest in connection with the manufacture of synthetic rubber. Both Shell Chemical and Shell Development Companies have been active in this development for a number of years, and have for some time been supplying from the small-scale plant at Emeryville, California, several tons a week of butadiene to rubber manufacturers.

These are only illustrations of the possibilities of chemical products from petroleum; among the many developments not touched upon is the wide variety of products from ethylene, such as ethyl alcohol, glycol and glycol ethers, and derivatives of acetylene, whose production from methane and other hydrocarbon gases has been shown to be feasible.

In the manufacture of chemicals from cracked petroleum gases the pioneers in the industry had attempted to react fairly complex mixtures of the various olefinic starting materials. This resulted in a multiplicity of main and side reaction products, with attendant difficulties of separation and purification. An important advance in manufacturing technique has been the separation of the mixture of hydrocarbons before reaction into small groups, such as C_3 (propane and propylene) or C_4 (butane and the butylenes), and the rigorous exclusion of harmful impurities such as sulfur compounds.

Not only have yields been improved by this means, but the resulting products themselves are produced eventually in high purity and of the unquestionable uniformity which is necessary for their application in many industries. For example, acetone used in the manufacture of artificial silk must be free from even the minutest amounts of active sulfur compounds, i.e., such as would corrode the metal spinnerets, whose constancy of diameter controls the denier of the silk fiber. When we first proposed to make acetone from petroleum gases, the head of a leading artificial-silk company stated that it would be impossible to think of meeting his requirements in this particular direction. In solving this problem the research laboratory first had to devise analytical methods applicable in the range of interest, i.e., of the order of 1 to 5 parts of sulfur in 10 million parts of acetone. The technique of such measurements was so perfected that we now are able not only to measure a total sulfur impurity of less than 5 parts in 10 million, but also to say within a 10-percent error how much of that impurity is due to the presence of free sulfur, hydrogen sulfide, mercaptan, or other form of active sulfur.

By rigorous control of processing — including the purity of raw materials—guided throughout by such precise analytical procedures, acetone and other chemicals are produced regularly in a high state of purity. In fact, the high level of scientific standards and scientific control of manufacturing operations, which has been necessary in the petroleum chemical industry, has reflected to the benefit of the oil industry as a whole.

Moreover, important changes have been brought about in the fundamental economics of the oil industry,

[*Continued on page 101*]

TABLE 2
Derived Chemicals from Olefins by Chlorination

NAME	FORMULA	Molecular Weight	Boiling Point (°C)	Specific Gravity (20/4° C)	Flash Point* (°F)	Solubility in Water (Percent by Weight at 20° C)
Allyl alcohol	$CH_2=CH-CH_2OH$	58.08	97	0.852	70	∞
Methallyl alcohol	$CH_2=C(CH_3)-CH_2OH$	72.10	114	0.852	90	20
Allyl chloride	$CH_2=CH-CH_2Cl$	76.53	45	0.937	—25	<0.1
Methallyl chloride	$CH_2=C(CH_3)-CH_2Cl$	90.56	72	0.926	10	<0.1
*Iso*crotyl chloride	$CH_3-C(Cl)=CHCl$	90.56	68	0.919	35	<0.1
1, 2, 3-trichloropropane	$CH_2Cl-CH(Cl)-CH_2Cl$	147.45	156	1.391	170	<0.1
Diallyl ether	$CH_2=CH-CH_2-O-CH_2-CH=CH_2$	98.14	95	0.808	20	0.3
Dimethallyl ether	$CH_2=C(CH_3)-CH_2-O-CH_2-C(CH_3)=CH_2$	126.19	134	0.816	15	<0.1
Glycerol α-monochlorohydrin	$CH_2OH-CH(Cl)-CH_2Cl$	110.55	213	1.320	280	∞
Glycerol dichlorohydrin	$CH_2Cl-CH(OH)-CH_2OH$	128.99	182	1.362	200	13
Epichlorohydrin	$CH_2Cl-CH(O)-CH_2$	92.53	117	1.181	90	6

* ASTM open cup.

Use of Lecithin in Gasoline

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LECITHIN, obtained from soybeans, is a phosphatide found to be effective in improving leaded and unleaded gasoline quality and stability. It has little effect on initial or dark storage color, but markedly reduces decolorization as well as haze and deposit formation when exposed to sunlight, as in gasoline-dispensing pumps. Its use results in decreased corrosion of storage-tank bottoms and of galvanized drums, particularly those containing highly leaded aviation gasolines in which the formation of zinc-oxide deposits often requires filtration prior to consumption. Reduced aluminum corrosion in aviation-gasoline tanks due to moisture condensation also was found. Dosages required range from 1 to 15 pounds per 1,000 barrels.

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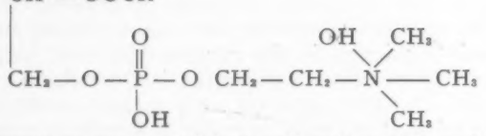
LECITHIN is a fat-like yellow or brownish substance of plastic consistency occurring in all living cells, and is the best known of a group of complex compounds known as phosphatides. Its structure may be depicted as follows:



R represents an unsaturated fatty acid such as oleic, and *R'* represents a saturated acid such as palmitic.

Lecithin forms colloidal solutions, and has found various applications as an interface modifier or emulsifier in the leather, textile, pigment, and food industries.

Until 1928 lecithin was derived wholly from animal sources, chiefly egg yolk, and was rather costly. Today lecithin is prepared commercially from soybeans by solvent extraction with hexane. Commercial soya lecithin includes other phosphatides, especially cephalin, and approximately 30 percent of residual oil, which imparts excellent storage and handling properties. It contains approximately 2.2 percent phosphorus; is soluble in benzol, chloroform, and petroleum ether; and is slightly soluble in alcohol, and is insoluble in acetone and water.

A. EFFECT ON SUNLIGHT STABILITY

The use of lecithin in gasoline was brought about as the result of a comprehensive study of various additives in an attempt to reduce or prevent the deterioration of both leaded and unleaded gasoline upon exposure to sunlight. Practically every refiner has noted that exposure of his gasoline in pump bowls, even for relatively short periods, results in cloudiness and fading, with occasional formation of a whitish deposit.[6,8,9] This cloudiness and deposit, due to the action of sunlight on the gasoline, is accelerated in leaded gasoline due to a gradual decomposition of the soluble tetraethyl lead to an insoluble compound believed to be lead triethyl hydroxide.[3,7]

After the examination of a large number of additives for this purpose, lecithin was found to be the best material and was studied in great detail.[1] The lecithin apparently acts as a peptizing agent, or protective colloid, in preventing the formation of a precipitate.

Effect of Lecithin on Gasoline in Sunlight

Samples of all types of leaded and dyed gasolines were exposed to direct sunlight in glass bottles, varying in size from 1 pint to 5 gallons, fitted with slotted cork stoppers. It was found that different gasolines reacted differently to this test, but in general all samples turned cloudy after an exposure of from a few minutes to several hours, followed by increasing cloudiness and the formation of a white deposit. The color of gasolines usually was affected detrimentally, as was the copper-dish gum and octane number.

The addition of lecithin to these gasolines prior to exposure results in a very marked improvement. The data indicated that lecithin retarded the deteriorating action of sunlight, but that the nature of this inhibiting action depended upon the nature of the gasoline, the effect being much less pronounced on straight-run gasoline than on cracked gasoline, and is shown in Tables 1 and 3.

Samples of ethyl fluid also were exposed to direct sunlight in a similar manner to that mentioned above. Table 2 indicates that lecithin very materially improved the sunlight stability of ethyl fluid, and was the only one of a large number of compounds tried which had this effect.

Larger amounts of lecithin even further increased the sunlight stability, and higher dosages of tetraethyl lead required additional quantities of lecithin for prevention of cloudiness.

Lecithin was found to have no effect on initial octane number or tetraethyl lead susceptibility. Although a slight reduction in octane number through loss of light fractions during the sunlight-exposure test was found in all cases, very little additional octane loss was noted in samples which were

TABLE 1

Effect of Lecithin in Various Types of Gasolines

(All Samples Contain 0.6 Ml TEL * Per Gallon and Dye)

Sample No.	GASOLINE TYPE	TREATMENT	Lecithin Dosage (Lb. Per 1,000 Bbl.)	Sunlight Exposure—Time for Cloud Formation	
				Without Lecithin (Minutes)	With Lecithin (Hours)
1	Cracked	Doctor	15	40	12
2	Cracked	Acid; caustic; steam-still; doctor	15	45	16
3	Cracked	Acid; caustic; clay vapor-treated; doctor	15	40	5
4	Straight-run	Doctor	15	25	2¾
5	Blend 60 percent No. 2 40 percent No. 4		15	45	12
6	Blend 60 percent No. 3 40 percent No. 4		15	45	8

* Tetraethyl lead.

TABLE 2

Effect of Lecithin on Sunlight Stability (3-Hour Exposure) of Ethyl Fluid

IDENTIFICATION	Cloud and Deposit Formation (Time in Hours)			Color	
	Clear For	Very Cloudy After	Deposit After	Initial	After 3 Hours
Fig. 1 Sample 1.....Ethyl fluid	¼	½	½	Yellow	....
Fig. 1 Sample 2.....Sample 1+10 percent lecithin	3+	..	.....	Yellow	Slightly faded yellow
Fig. 2 Sample 7.....Same as sample 1	..	..	.....	..	..
Fig. 2 Sample 8.....Same as sample 2	..	..	.....	..	..
Fig. 2 Sample 9.....Sample 1+5 percent alpha-naphthol	Black	..	18-Hour Settling	Yellow	Black
Fig. 2 Sample 10.....Sample 1+3 percent monobezyl para aminophenol	Black	..	18-Hour Settling	Yellow	Black

TABLE 3

Effect of Lecithin on Sunlight Stability (3-Hour Exposure) of Leaded Gasoline

(All Samples Contain 1.5 Ml TEL Per Gallon and Dye)

IDENTIFICATION	Cloud and Deposit Formation (Time in Hours)			Color		Initial Copper-Dish Gum (Mg Per 100 Ml)	Initial ASTM Gum (Mg Per 100 Ml)
	Clear For	Very Cloudy After	Deposit Found After	Initial	After 3 Hours		
Sample 1.....Doctor-sweetened cracked gasoline	1/6	unreported	unreported	Copper	Yellowish	77	4
Sample 2.....Sample 1+lecithin (15 lb. per 1,000 bbl.)	3+	..	.....	Copper	Light copper	17	2
Fig. 1 Sample 3...Sample 1+ alpha-naphthol (30 lb. per 1,000 bbl.)	1/6	½	18-hour settling	Copper	Yellowish	16	5
Fig. 1 Sample 4...Sample 1+alpha-naphthol (30 lb. per 1,000 bbl.) +lecithin (15 lb. per 1,000 bbl.)	3+	..	.....	Copper	Light copper	19	4
Fig. 1 Sample 5...Acid-treated, steam-stilled and doctor-sweetened cracked gasoline	½	1	18-hour settling	Copper	Yellowish	4	3
Fig. 1 Sample 6...Sample 5+lecithin (15 lb. per 1,000 bbl.)	3+	..	.....	Copper	Yellowish	8	2
Fig. 2 Sample 11..Acid-treated, steam-stilled and doctor-sweetened cracked gasoline	½	1	18-hour settling	Copper	Yellowish	4	3
Fig. 2 Sample 12..Sample 11+lecithin (15 lb. per 1,000 bbl.)	3+	..	.....	Copper	Yellowish	8	2
Fig. 2 Sample 13..Sample 11+alpha-naphthol (15 lb. per 1,000 bbl.)	¼	½	18-hour settling	Copper	Yellowish	5	1
Fig. 2 Sample 14..Sample 11+monobenzyl para aminophenol (15 lb. per 1,000 bbl.)	¼	½	18-hour settling	Copper	Yellowish	5	1
Sample 15.....Sample 11+alpha-naphthol (15 lb. per 1,000 bbl.) + lecithin (15 lb. per 1,000 bbl.)	3+	..	.....	Copper	Yellowish	4	1
Sample 16.....Sample 11+monobenzyl para aminophenol (15 lb. per 1,000 bbl.)+lecithin (15 lb. per 1,000 bbl.)	3+	..	.....	Copper	Light copper	4	1
Sample 17.....Doctor-sweetened straight-run gasoline	1/12	¼	18-hour settling	Copper	Pink	7	1
Sample 18.....Sample 17+lecithin (15 lb. per 1,000 bbl.)	1½	2	18-hour settling	Copper	Pink	12	3
Sample 19.....Sample 17+lecithin (30 lb. per 1,000 bbl.)	3+	..	.....	Copper	Pink	..	..

TABLE 4

Effect of Steam Stilling, before Doctor Sweetening, on Lecithin Susceptibility

(All Samples Contain 0.8 Ml TEL Per Gallon)

Sample No.	Gasoline Type	TREATMENT	Lecithin Dosage (Lb. per 1,000 Bbl.)	Sulfur Content (Percent)	Sunlight-Exposure Time for Cloud Formation		Color	
					Without Lecithin (Hours)	With Lecithin (Hours)	Initial	After 8 Hours
1	Straight-run	Caustic; acid; caustic; *doctor; steam-still* and doctor	15	0.107	½	8	Copper	Pale copper
2	Straight-run	Caustic; acid; caustic; *steam-still* and *doctor*	15	0.253	¼	3½	Copper	Pink

TABLE 5

Effect of Sulfur Compounds on Sunlight Stability

(All Samples Contain 0.8 Ml TEL Per Gallon and Dye)

Sample No.	GASOLINE TYPE	Treatment	Lecithin Dosage (Lb. per 1,000 Bbl.)	Sunlight-Exposure Time for Cloud Formation		Color	
				Without Lecithin (Hours)	With Lecithin (Hours)	Initial	After 24-Hour Sun Test
1	Straight-run	Doctor	15	¾	2½	Copper	Pale salmon
2	Sample 1+0.015 percent ethyl disulfide		15	¾	2½	Copper	Pale salmon
3	Sample 1+0.015 percent butyl sulfide		15	¾	2½	Copper	Pale salmon
4	Straight-run	Doctor	15	½	2½	Copper	Pale salmon
5	Sample 4+0.005 percent sulfur		15	½	2	Copper	Pale salmon
6	Sample 4+0.010 percent sulfur		15	¼	2	Copper	Pale salmon
7	Sample 4+0.010 percent sulfur +0.2 percent ethyl disulfide		15	¼	1½	Copper	Pale salmon
8	Blend 60 percent cracked and 40 percent straight-run	Doctor	15	1	24+	Copper	Bleached
9	Sample 8+0.002 percent sulfur		15	¾	8	Copper	Bleached
10	Sample 8+0.01 percent sulfur		15	¾	2½	Copper	Bleached
11	Sample 8+0.02 percent sulfur		15	¼	2	Copper	Bleached
12	Sample 8+0.07 percent ethyl disulfide		15	1	8	Copper	Bleached

only slightly cloudy over those which remained clear; but up to 12 octane numbers were lost on certain samples which formed heavy cloud and deposits. This reduction in octane appears to be related to the amount of cloud formed, and for similar-type gasolines appears to be proportional to the amount of tetraethyl lead present in the original samples.

The copper-dish-gum test (Atlantic Refining Company method) of the base gasoline before sunlight exposure was not affected materially by lecithin at values below 20 to 30 mg per 100 ml. In the majority of cases, an increase of less than 5 mg was noted in this range.[4] At high copper-dish-gum values, above 70 to 100 mg per 100 ml, a reduction generally was noted. Lecithin, therefore, appears to inhibit tetraethyl lead decomposition, and does not act as a strong gum inhibitor.[2] After sunlight exposure, however, the base gasolines containing cracked components showed considerably increased copper-dish-gum values, but the action of lecithin was such as to minimize the detrimental effect of the exposure.

The effect of lecithin on the Saybolt color of the base gasoline before leading and dyeing was found to be negligible. The colors of the leaded samples after exposure, however, were found to vary from pink to yellow when using either red or copper-colored samples, as shown in Table 3.

Effect of Sulfur Compounds on Sunlight Stability

The sunlight stability of leaded gasolines was noted to be related to their sulfur content. It was found that doctor sweetening, using a minimum amount of sulfur, resulted in slightly better sun tests, due to the formation of a minimum amount of polysulfides. Sweetening before steam stilling also resulted in lower sulfur-content stocks, with better sunlight stability, through a reduction in the amount of free and disulfide sulfur present, as shown in Table 4, and rendered the gasoline much more susceptible to the stabilizing effect of lecithin.

A fundamental study of the effect of free sulfur, organic sulfides, and di- and polysulfides accordingly was conducted. Table 5 indicates that elementary sulfur acts as an accelerator of the action of sunlight in leaded gasoline. Inasmuch as the use of the usual copper-strip corrosion test or the Universal Oil Products Company butyl-mercaptan test limits free sulfur to a very small amount, little trouble should be experienced in this connection, provided the sweetening operation is controlled carefully.

Copper sweetening was investigated also, and gasolines so sweetened were found to have sunlight stabilities essentially equal to samples sweetened by the carefully controlled doctor method, and also were benefited by the use of lecithin.

Effect of Lecithin in Pure Leaded Organic Compounds

An attempt was made to determine the reason why lecithin is so much more effective in retarding the effect of sunlight on cracked gasolines than on straight-run gasolines. It was believed that working with pure organic compounds might furnish some light on the matter.

Accordingly samples of *iso*octane, cyclohexane, and xylene were leaded with 0.8 ml of tetraethyl lead per gallon and exposed to sunlight for 2 days. Lecithin affords protection in all three cases, but it is least effective with the *iso*paraffin tested, as shown in Table 6.

Effects of Components of Lecithin on Sunlight Exposure

As lecithin is derived from the choline ester of palmitic, stearic or oleic ester of glycerylphosphoric acid, its properties possibly might be due to one or more of these groups. Therefore, samples of choline and oleic, palmitic and glycerylphosphoric acid were tested separately for their effect on sun stability of leaded gasoline, without success. Lecithin alone appears to have the unusual property of stabilizing gasoline in this respect.

Combinations of Lecithin with Other Inhibitors

During the course of this investigation, it was noted that certain gasolines required the use of an auxiliary agent with lecithin to effect the desired stability. Several anti-oxidants were tried, and it was noted that products such as monobenzyl para aminophenol, alpha-naphthol, catechol, and pyrogallol, which in themselves had no stabilizing effect on cloud or deposit formation in sunlight, improved the

TABLE 6

Effects of Lecithin on Pure Leaded Organic Compounds Containing 0.8 Ml TEL Per Gallon

Compound	Lecithin Dosage (Lb. Per 1,000 Bbl.)	Sunlight-Exposure Time for Cloud Formation	
		Without Lecithin (Hours)	With Lecithin (Hours)
*Iso*octane	15	1	5
Cyclohexane	15	1	48+
Xylene	15	1	48+

light-stabilizing properties of lecithin.[1,9] Certain of these inhibitors, viz., pyrogallol and monobenzyl para aminophenol, resulted in impaired colors after sunlight exposure; whereas commercial phenol, having a relatively poor gum-inhibiting tendency, often bleached the original color. It was found that a combination of these strong gum inhibitors with commercial phenol and lecithin greatly improved the sunlight stability of leaded gasolines from the standpoint of cloud formation and color change.[5] Table 7 shows typical results obtained on leaded gasoline. Table 8 shows similar results on unleaded gasolines by the use of aromatic ring compounds, such as alpha-naphthol or anthracene.

Effect of Lecithin on Accelerated-Gum Test

In addition to the effects previously reported, it was found that lecithin was a valuable additive for the stabilization of the accelerated-gum test (Army method) in aviation gasolines. Table 9 shows data covering the stability of typical leaded aviation gasolines, and indicates that the accelerated-gum content of gasolines which tends to increase on storage may be stabilized by the use of lecithin.

Effect of Dark Storage on Lecithin

In order to determine whether lecithin lost its inhibiting effect on prolonged storage in closed dark containers, samples of various types of gasolines were stored with and without lecithin, both dry and over water, for a period of one year, and tested for sunlight stability. The results obtained in all cases indicated that lecithin was as effective in the stored samples as it had been initially.

Effect of Lecithin in Automobile and Airplane Engines

After several years of full-scale refinery production of gasolines containing lecithin, examinations of engines using lecithin-treated gasolines did not reveal any deleterious effects, and it appears entirely harmless.

B. EFFECT ON CORROSION OF IRON AND GALVANIZED IRON

A separate and distinct function of lecithin was noted during the course of the previously reported work. This was its effect on the prevention of corrosion of iron and galvanized-iron containers by both unleaded and leaded gasolines.

It has been known for years that leaded gasoline was very slightly corrosive to tanks and drums used for its storage.[3] With the rapid increase in the use of highly leaded gasolines in recent years, the problem became more acute, because the degree of corrosion appeared to be linear with the amount of tetraethyl lead present, and particularly so as the presence of water aggravated this corrosion. It is common practice to use water as a seal in the bottom of large storage tanks, and means of combating this corrosion are of importance.

The reason for this increased corrosion of iron and galvanized iron by leaded gasoline in the presence of water is not known definitely, but is indicated to be due to the presence of free bromine or chlorine liberated from the ethylene dibromide and ethylene dichloride present in the tetraethyl lead fluid to reduce lead deposits in the engine, after combustion. These halides probably combine with the water present to form corrosive hydrobromic or hydrochloric acid.

Inasmuch as lecithin already had been found to prevent deterioration of tetraethyl lead fluid alone,[3] its effect on the corrosion problem was investigated. Samples of unleaded and leaded gasoline with and without lecithin were stored, both dry and over water, to observe the corrosive effect on small strips of carefully cleaned iron and galvanized iron in stoppered glass bottles. After one year, examination of the strips indicated:

1. In the absence of water, all strips were free of corrosion.
2. In the presence of water and unleaded gasoline, all strips were corroded considerably, particularly that part of the strip which had been immersed in the water. The corrosive effect of the water was more pronounced in leaded gasoline.
3. The alkalinity of the water appeared to reduce the corrosion of leaded gasoline, as greatest corrosion was found in the presence of distilled water.
4. The use of lecithin, amounting to 5 to 10 pounds per 1000 barrels in leaded gasoline greatly reduced the corrosion of both iron and galvanized iron.

These tests were followed by actual storage in iron and galvanized-iron drums, and the results were found to agree closely with those reported hereinbefore. Observation of a large number of storage tanks over a period of years confirmed the fact that leaded gasoline was more corrosive than unleaded gasoline, and that its corrosive effect could be remedied by the use of lecithin.

Effect of Lecithin on Gasoline Stored in Drums

Considerable trouble has been encountered by petroleum marketers in preventing the formation of

TABLE 7
Effect of Combinations of Lecithin with Other Inhibitors
(All Samples Contain 0.8 Ml TEL Per Gallon)

Sample No.	GASOLINE TYPE	TREATMENT	Lecithin Dosage (Lb. per 1,000 Bbl.)	Sunlight-Exposure Time for Cloud Formation		Color	
				Without Lecithin (Hours)	With Lecithin (Hours)	Initial	After 24 Hours
1	Blend 70 percent straight-run and 30 percent cracked	Acid; caustic; doctor; steam-still; doctor	15	¼	1½	Copper	Pale salmon
2	Sample 1+7 lb. per 1,000 bbl. monobenzyl para aminophenol+0.02 percent cresylic acid		15	¼	23	Copper	Copper
3	Straight-run	Doctor	10	½	3½	Copper	Pale salmon
4	Sample 3+7 lb. per 1,000 bbl. monobenzyl para aminophenol+0.02 percent cresylic acid		10	½	24+	Copper	Copper
5	Cracked	Acid; caustic; doctor; steam-still; doctor	5	1½	4	Copper	Yellowish
6	Sample 5+7 lb. per 1,000 bbl. monobenzyl para aminophenol+0.02 percent cresylic acid		5	1½	24+	Copper	Copper

TABLE 8

Effect of Combinations of Lecithin with Other Inhibitors

(All Samples Contain No TEL)

Sample No.	GASOLINE TYPE	Treatment	Lecithin Dosage (Lb. per 1,000 Bbl.)	Sunlight-Exposure Time for Cloud Formation	
				Without Lecithin (Hours)	With Lecithin (Hours)
1	Straight-run	Doctor	5	½	4
2	Sample 1+alpha-naphthol (10 lb. per 1,000 bbl.)		5	½	18+
3	Blended, cracked, and straight-run	Acid; caustic; steam-still and doctor	10	2	5
4	Sample 3+anthracene (5 lb. per 1,000 bbl.)		10	4	12
5	Sample 3+anthracene (10 lb. per 1,000 bbl.)		10	4	18+

TABLE 9

Effect of Lecithin on Accelerated-Gum Test (Army Method)

(All Samples Contain 4 Ml TEL Per Gallon)

Sample No.	GASOLINE TYPE	Accelerated Gum (Mg Per 100 Ml)					
		Initial		One Month		Two Months	
		Without Lecithin	With Lecithin*	Without Lecithin	With Lecithin*	Without Lecithin	With Lecithin*
1	Straight-run aviation	2	1	3	3	5	1
2	Blended aviation 60 percent sample 1 40 percent *iso*octane	3	1	25	4	45	6
3	Blended aviation 50 percent sample 1 50 percent alkylation gasoline	4	4	37	3	40	6

* 10 lb. per 1,000 barrel lecithin added.

zinc oxide in galvanized-iron drums containing leaded gasoline. On quiescent storage this material tends to settle to the bottom of drums, but is dispersed readily throughout the drums during movement. In aviation gasoline, particularly, such a deposit is highly objectionable, and commercial air lines go to extreme measures to prevent this material from entering their fuel tanks. Filtration through chamois sometimes is resorted to, but is extremely slow if much zinc oxide is present.

Although especially processed containers can be obtained, this is relatively expensive, and should be avoided if a cheaper and dependable gasoline treatment can be found. Lecithin was tried in this connection and found to be extremely effective in eliminating this formation of zinc oxide in the absence of water, and in materially reducing it in the presence of water when used in dosages of 5 to 15 pounds per 1000 barrels.

It has been noted also that leaded aviation gasoline, particularly, sometimes was decolorized or changed from blue to pale green by the action of the lead on the galvanized drums in the presence of water. This decolorization also was found to be practically eliminated by the use of lecithin.

C. EFFECT ON CORROSION OF ALUMINUM

With the adoption of increased tetraethyl lead in aviation gasoline, it developed that certain commercial air lines were experiencing considerable difficulty with the corrosion of aluminum fuel-tank bottoms. The cause was believed to be the condensation of moisture from the air drawn into the tanks as the fuel was consumed. It was found, by actual observation, that aviation gasolines containing lecithin were relatively free of this corrosion under service conditions, and a laboratory investigation was conducted to verify this effect. Available data show that the presence of either tetraethyl lead fluid or ethylene dibromide causes considerable corrosion of aluminum in the presence of water, and that this corrosion largely can be eliminated by the use of lecithin.

D. COST OF TREATMENT WITH LECITHIN

Each refiner and each gasoline will require a different amount of lecithin to effect the results set forth herein, depending upon the susceptibility of the gasoline to lecithin and upon the desired storage stability. With dosages ranging from 1 to 15 pounds per 1000 barrels of gasoline, the cost of lecithin stabilization ranges from $0.0004 to $0.0056 per barrel.

CONCLUSIONS

As a result of these investigations, it is concluded that lecithin is effective in improving the quality of gasoline without any detrimental effects, and allows the refiner to improve his products along lines demanded by the high-octane leaded fuels of today at a minimum of expense. In addition, tankage and drum-maintenance expense is lessened due to reduced corrosion. Furthermore, it furnishes the farmer another outlet for farm products, i.e., in the petroleum industry.

Acknowledgment

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Engine Performance As Influenced By Ignition Timing Maintenance

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It is recognized generally that the best performance for which an engine can be designed is limited by the anti-knock value of the fuels available. The attainment of this peak performance requires a delicate combination of spark timing and compression ratio; consequently, the continued maintenance of that adjustment of the timing mechanism which the engine designer intended to be used is necessary if best performance is to be expected.

The accumulated information indicates that timing mechanisms of a small percentage of cars are allowed to become advanced in service, so that the octane requirements of those cars are increased sufficiently to cause present-day fuels to knock, with no improvement in engine performance. An even larger percentage of cars has been found to operate with the spark timing retarded excessively, causing definite reduction in performance.

Although the importance of correct spark timing has become common knowledge through the cooperative studies of various groups, it can be likened to the weather, concerning which Mark Twain once said that nobody ever does anything about it. Greater care in maintenance of correct timing not only would insure improved performance with present-day fuels—it also would reduce the number of cases in which detonation is obtained with today's fuels.

This paper was Presented to Division of Refining, before Twenty-first Annual Meeting of the American Petroleum Institute, Chicago, November 15, 1940.

THE importance of spark timing and its relationship to engine performance has been recognized by both the automotive and petroleum industries during the past several years. With a gradual increase in compression ratios of engines designed to meet the demand for more power and greater economy, the time of igniting the charge has become more and more critical in order to obtain optimum performance. The increase in octane requirement accompanying these changes in design likewise has become more critical. Not only has the octane-requirement level been raised, but the variation from car to car has become much more serious. This is true because the refiners necessarily must supply the demand with usually two, and not more than three, octane-number grades of fuel. An unnecessary waste of high-octane gasoline is evident if only a few cars of high-octane requirement control the general octane-number level of gasolines being marketed.

In numerous papers[1] investigators have shown the relationships found by them to exist between power, economy, octane requirement, and spark timing. It is not our object to try to improve or amend the relationships found in the individual laboratories by presenting data obtained in the course of our own research projects, but rather to attempt to piece together the data that are already available. There is available a considerable mass of data on this subject, which has been gathered from all parts of the country. The American Petroleum Institute, for example, has conducted cooperative surveys for a number of years to obtain a representative picture of the octane requirements of cars, and particularly since 1937 has it directed the survey toward a study of the major factors influencing the wide spread in octane requirement. From these data, submitted by many laboratories, it is possible to obtain indisputable evidence of the influence of various factors on engine performance in service, and a good cross-sectional view of the octane-requirement picture. It is the purpose of this paper to discuss these data from the surveys of the past several years, and to present as simply as possible relationships showing the influence of spark timing on engine power, economy, and octane requirement.

Power that Should Be Obtained with Distributors Set as Recommended

In order to understand the significance of the data obtained by the survey group on spark timing and its relation to power, it is necessary to consider the problem of design involved. The high compression ratios of today's engines are justified solely for obtaining good economy. A marked increase in engine power cannot be obtained by relatively great increases in compression ratios. The increase in torque with increase in compression ratio is shown for a single-cylinder engine in Figure 1. The curves for a 100-octane fuel and a 70-octane fuel show the relative difference in maximum torque available at different compression ratios. Using the 100-octane fuel no detonation was encountered, and the mixture strength and spark timing were adjusted to maximum torque at each compression ratio. With the 70-octane fuel the mixture was set for maximum torque, but it was necessary to adjust the spark to maintain detonation at a light knock intensity. At a compression of 5.5:1 both fuels gave the same torque. However, at a compression ratio of 6.5:1 it was necessary to retard the spark 6 degrees for the 70-octane fuel, resulting in a 2-percent loss in torque. These figures illustrate rather well the compromise being used in modern engines in which high compression ratios are utilized to obtain good economy at light and intermediate loads. By employing a judicious control of the spark timing to control detonation on currently marketed fuels, some gain in power is realized at full load over that which would be obtained with lower compres-

sion ratio. The retardation of spark timing that in general is necessary entails the loss of only a very small percentage of the total amount of power that would be available on a non-knocking fuel at these compression ratios.

Data obtained by the Automotive Survey Committee on cars in normal service reveal to what extent this compromise actually results in a loss of power. With distributors set to factory specifications, Figure 2 shows the average spark retard from that required for maximum torque, and also the resulting loss in torque. It will be noted that at low speeds the average standard distributor retards the spark 7 degrees, and at high speeds 5 degrees. This spark retard resulted in a 3-percent loss in torque at low speeds, and less than a 2-percent loss at high speeds for 13 cars.

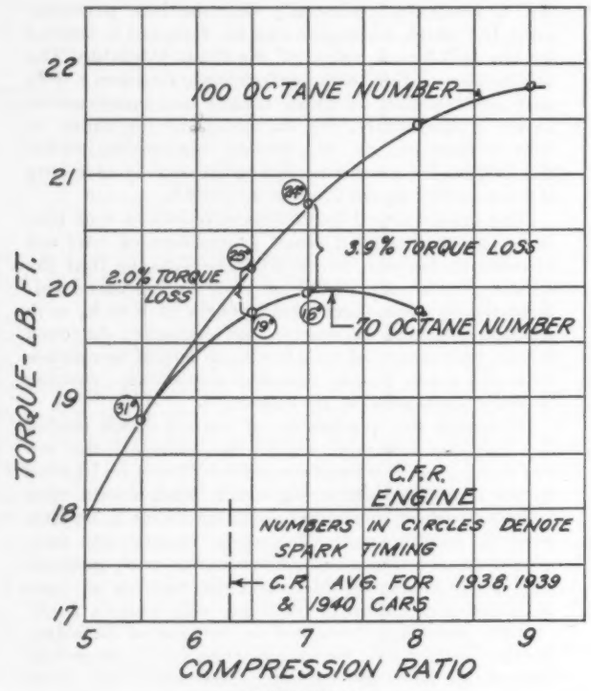

FIGURE 1
Illustration of Torque Obtainable on Two Fuels at Several Compression Ratios.

In further confirmation of the above relationship, data were obtained on 28 cars at maximum-torque engine speed. At factory distributor setting the average spark-timing retard from that required for maximum torque was 6.4 degrees. This resulted in an average loss in torque of 3 percent. It may be interesting to note that in 20 of these cars additional data were obtained by setting the distributor to trace knock on a 70-octane fuel. The resulting retard in spark timing from that giving maximum torque was 6.8 degrees and a 3.1-percent loss in torque. It is thus quite evident that engines which have distributors set to factory specifications suffer only a small loss in power, which is of the order of 2 or 3 percent. It is evident also that, when using regular-grade fuels of about 70 octane number, approximately the same reduction is experienced.

Economy

Inasmuch as cars are operated at part throttle the greater portion of the time, the effect of spark timing on economy at part load is probably of greater importance than its effect on performance at full load. The majority of 1938- and 1939-model engines have vacuum-controlled distributors which automatically advance the spark, when the throttle is partly closed, as much as 20 degrees from the full-load setting. Thus, although the spark may be retarded several

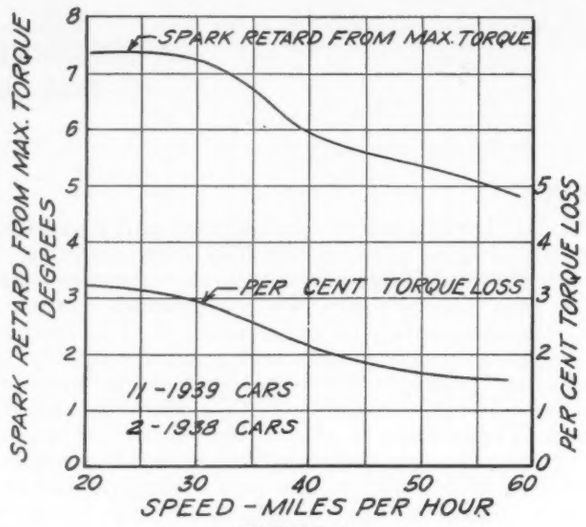

FIGURE 2
Average Spark Retard with Standard Distributor and Accompanying Loss of Torque in 13 Cars.

degrees to prevent knock at full load, it is quite possible to obtain optimum timing at part load with regular fuels. To illustrate just what the spark-timing requirements for maximum economy are at various throttle openings, Figure 3 has been prepared from data obtained on one 1939-model car. In this particular car the spark timing of the standard distributor at level-road load was almost identical with the curve shown for maximum economy.

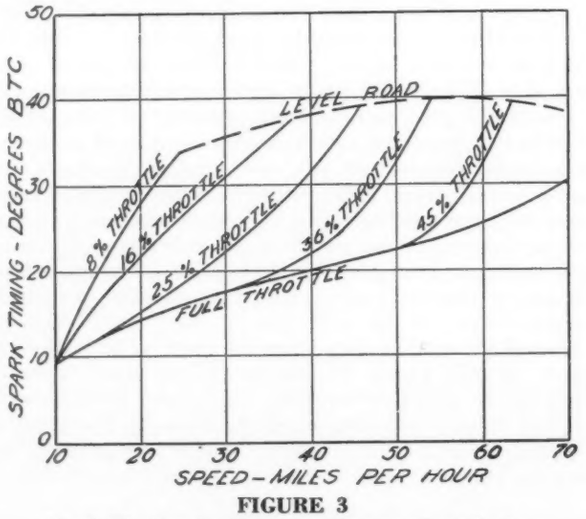

FIGURE 3
Spark Timing for Maximum Economy at Various Throttle Openings on a 1939 Car.

Although much has been said about the octane requirement at full throttle, few data are available on the octane requirement at part throttle. Figure 4 shows a rather complete picture of the octane requirement of the same 1939 car at various throttle openings, with spark set for maximum economy as shown

in Figure 3. Each curve in Figure 4 is obtained from a complete reference-fuel framework of incipient-knock spark-timing curves covering a wide range of reference fuels. It is surprising to note here just how low the octane requirement is at level-road load, being less than 15 octane number below 40 miles per hour and increasing up to only 55 octane number at 70 miles per hour. The full-throttle maximum-performance octane requirement is well in line with other cars, varying from 86 octane number at low speed to 75 octane number at high speed. The difference between the level-road and full-throttle octane requirements is the price paid in octane number for the power necessary for acceleration and climbing hills.

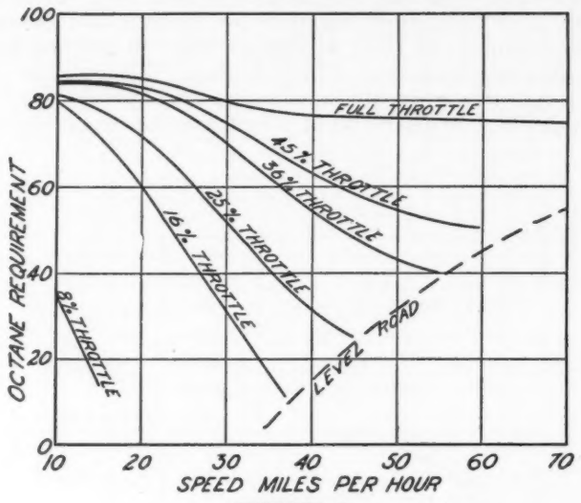

FIGURE 4

Octane Requirements at Various Throttle Openings with Spark Set for Maximum Economy on 1939 Car.

In the previous discussion of the spark timing which is used at full throttle and that necessary for maximum economy under level-road conditions, it is quite evident that a distributor, which at factory setting gives optimum timing at part throttle, will be over-advanced if the basic setting is increased in an effort to gain a small amount of power at full load. The survey data shown in Table 1 give evidence that little is to be gained in economy by advancing the distributor. In one car a slight loss in economy was experienced at an advanced setting. The car which shows a marked increase in economy was one which was not equipped with a part-throttle spark control.

Causes of Wide Variation in Octane Requirement

The influence of spark timing on power and economy already has been shown, together with the octane number required under standard conditions. However, the maintenance of the ignition system at proper timing is also one of the major factors controlling the extremes in octane requirement of some cars. To demonstrate the necessity of care in adjusting the distributor basic settings, curves have been taken from the survey data for three low-priced cars. These curves, shown in Figure 5, indicate the rapid change in octane requirement, corresponding to a change in the initial spark advance. Using data of eight cars, it was found that the average change in octane requirement per degree change in timing was approximately 1.5 octane units for retarded distributor, and approximately 1 octane unit for advanced distributor. This rapid change in octane requirement for relatively small changes in spark timing results in a rather wide spread of octane requirements in cars in which the ignition system properly is not maintained mechanically. The accessibility of most distributors adds to the possibility that they may be put in improper adjustment by operators who are not acquainted with the importance of proper ignition timing.

In Figure 6 octane numbers are plotted against the accumulated percentage of cars giving no knock, using cars as they operate in service, and also using cars with spark timing set to factory specifications. It will be seen that approximately 40 percent had low octane requirements as a result of retarded timing, and that 5 percent had extremely high requirements because of excessively advanced timing. It is also quite evident that, when the spark timing is corrected, the spread in octane requirements becomes much smaller. Although it may not be pertinent to the subject, the distribution curve for these same cars with combustion-chamber deposits removed is shown, illustrating rather definitely that deposit accumulation is another very important factor in raising the level of octane requirement.

TABLE 1

Effect of Basic Spark Advance on Part-Throttle Economy

SPARK ADVANCE (Degrees from Standard)	Percent Relative Fuel Economy at 40 MPH and Road Load Referred to Standard Spark Advance				
	1938 Car E	1938 Car A	1938 Car B	1938 Car C	1936 Car D
6 retarded	91.5	99.5	100.0	94.4	....
3 retarded	96.6	99.8	100.2	98.2	98.8
0	100.0	100.0	100.0	100.0	100.0
3 advanced	102.7	100.2	99.7	101.1	100.6
6 advanced	104.5	100.6	99.3	101.9	100.8
9 advanced	105.9	101.0	98.8	102.6	100.9
12 advanced	107.0	101.3	96.1	103.2	100.3

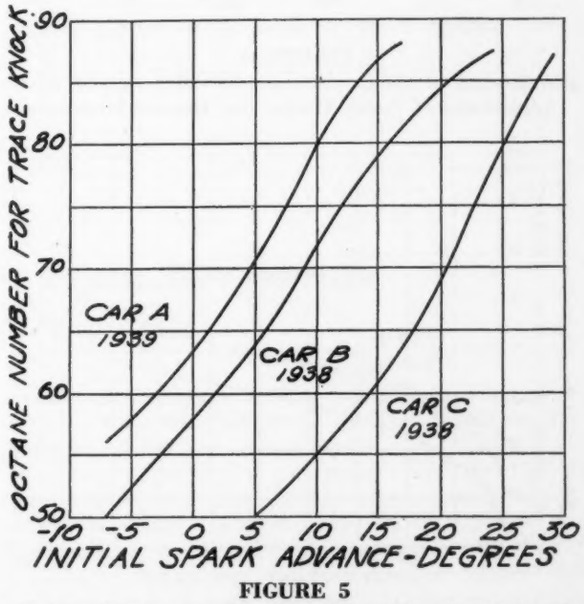

FIGURE 5

Octane Number for Trace of Knock Vs. Initial Spark Advance on Three Cars.

Spark-Timing and Octane-Requirement Trends

One of the important services rendered by the survey conducted each year is the indication of the

effect of changes in automotive equipment on the trend in fuel requirements from year to year. Also, any particular make of car which gets out of line at once will be evident. In this respect the surveys conducted in the last two years have accumulated considerable data on 1937, 1938, and 1939 cars, with considerable emphasis being placed on the Ford, Chevrolet, and Plymouth. Figure 7 shows the basic distributor setting of these three cars, as found in service, plotted against the accumulated percentage

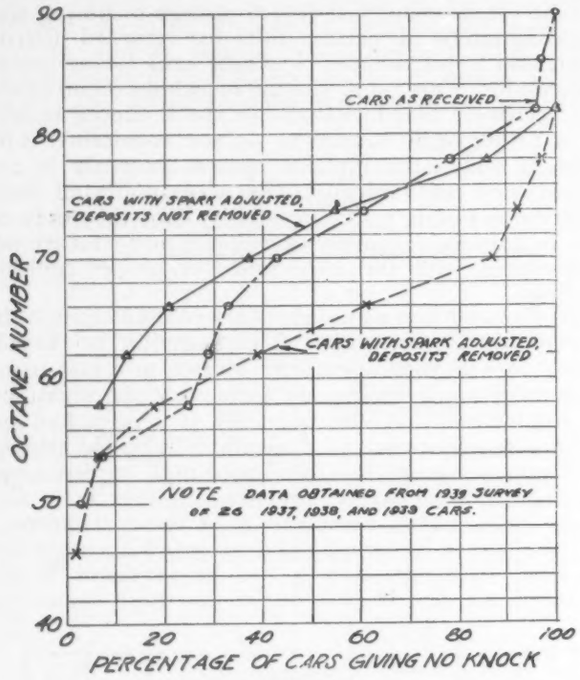
CARS AS RECEIVED
CARS WITH SPARK ADJUSTED, DEPOSITS NOT REMOVED
CARS WITH SPARK ADJUSTED, DEPOSITS REMOVED
NOTE DATA OBTAINED FROM 1939 SURVEY OF 26 1937, 1938, AND 1939 CARS.
OCTANE NUMBER
PERCENTAGE OF CARS GIVING NO KNOCK

FIGURE 6
Distribution of Octane Requirement Before and After Adjustment of Spark Timing and Deposit Removal.

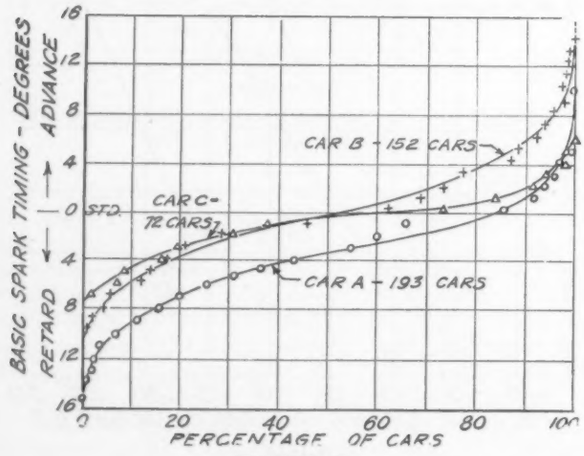

FIGURE 7
Distribution of Variation of Spark Timing from Standard for Three Makes of 1937, 1938, and 1939 Cars.

of cars. It will be noted here that one car in particular shows a definite tendency toward retarded spark timing. For the other two makes the greater percentage of cars are grouped between 4 degrees retard and 4 degrees advance. Figure 8 shows that in 1937 and 1938 approximately only 25 percent of the cars were over-advanced from standard setting, whereas in 1939 approximately 50 percent were over-advanced. Considering a total of 410 cars, including nearly all makes for 1937, 1938, and 1939, Figure 9 shows a general tendency for the cars to have a slightly retarded spark timing, with 20 percent being retarded more than 5 degrees, and 5 percent being advanced more than 5 degrees.

This apparent lack of proper spark-timing maintenance of cars in service is reflected in the octane-requirement picture. Figure 10 shows that, for 1937 and 1938 cars, approximately 75 percent had octane requirements of 70 or lower, whereas 10 percent had octane requirements of 75 or higher. Although hardly enough data were obtained in the 1939 survey to give a comparable distribution curve, the curves shown in

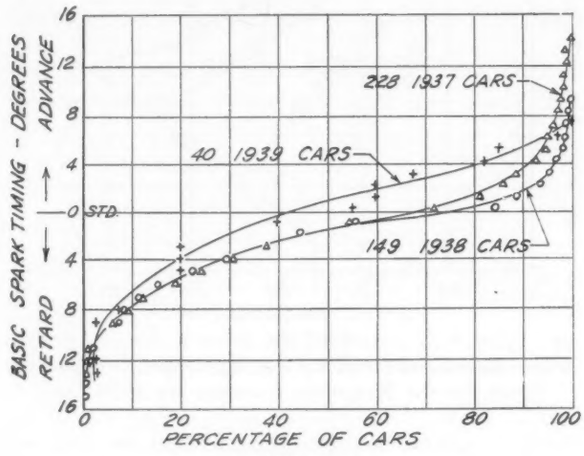

FIGURE 8
Trend in Maintenance of Basic Spark Setting from 1937 to 1939.

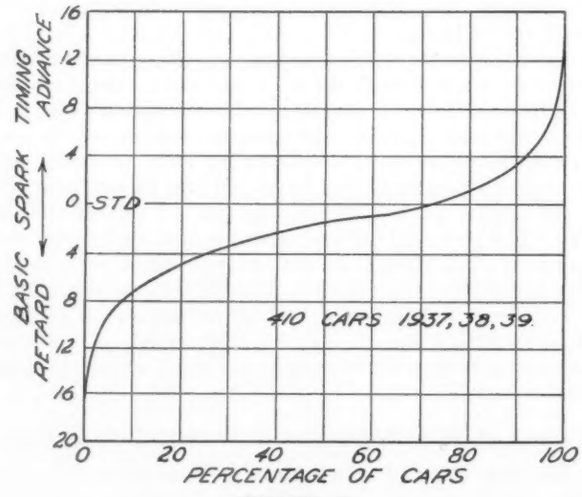

FIGURE 9
Distribution of Basic Spark Timing of Cars as Found in Service.

Figure 6 for cars, as received, indicate that the general octane-requirement level had increased in 1939. This corresponds in large part to the general increase in spark advance shown in Figure 8.

Although data are not yet available on the 1940 API survey, data obtained in our own laboratory indicate that the general trend of advanced spark timing and octane requirements shown for 1939 probably will be increased this year. This is closely related, no doubt, to the general increase in regular-

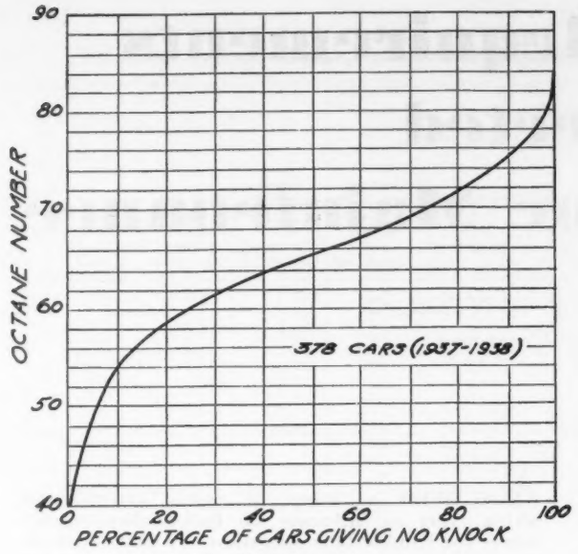

FIGURE 10
Distribution of Octane Requirement of 1937 and 1938 Cars as Found in Service.

grade gasoline during the past two years to 74 octane number.

Conclusion

In conclusion, it must be pointed out that the modern engine is designed to operate on currently available fuels of 70 to 74 octane number. The compression ratio is such that fuels of that octane number give no trouble at part load, with mixture strength and spark timing adjusted to maximum economy. The rather insignificant loss of 2 or 3 percent in power at full load, because of spark retard to prevent detonation, is taken care of amply by the size of the engine. It is not logical to assume that an increase in the octane number of fuel to 85 to prevent this small loss is a desire of the engine designer. When production of fuels of higher octane number is economically possible, it is safe to predict that compression ratios will be raised accordingly to get better economy; but the same compromise will have to be made at full load, and the spark retarded to prevent detonation.

Survey data of the past several years have served admirably to inform the engine builders and petroleum refiners of the performance of both their products in service. It has been shown that the power loss at full load, when the maufacturer's recommendations as to spark timing are adhered to, is no greater than was expected. The operation of engines on current fuels at part load is entirely satisfactory and allows maximum economy to be realized.

Although the general high level of octane requirements is caused to a considerable extent by the accumulation of combustion-chamber deposits, the excessively high octane numbers of present-day gasolines are a wasteful attempt to satisfy the few cars which have excessively advanced spark timing—often with actual reduction in performance.

It must be emphasized again that ignition timing should be maintained in accordance with the manufacturer's recommendation; both by maintaining the distributor in good mechanical condition, and by intelligent and judicious timing of the engine. Such maintenance would result in less unnecessary loss of power, and materially would reduce the number of cars of high octane requirement, which greatly have advanced spark timing either through neglect or unintelligent adjustment.

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Synthetic Chemicals From Petroleum

[*Continued from page 91*]

as a result of its entrance into the field of synthetic chemicals. Thus the guiding principal of Shell Chemical Company's first operations was to utilize refinery gases that otherwise would go to waste or, at most, be consumed as fuel. It would have been difficult to foresee the revolution in gasoline manufacture which was to come about as a result of one of the steps in secondary-butyl-alcohol synthesis — the step which consisted in removal of the *iso*butylene content of the feed by absorption in cold sulfuric acid, and recovery of the acid by heating, which polymerized the *iso*butylene to di*iso*-butylene, the source of *iso*octane.

With the recognition of the possibilities of *iso*octane in aviation fuel came the development of the process as a refinery operation; and it soon became a question not of finding outlets for waste products, but of supplying enough raw materials for the needs in both chemical and synthetic-gasoline fields. This has led to the development, on the one hand, of the hot-acid polymerization process and the alkylation process, which utilize a greater proportion of the available hydrocarbon feeds; and, on the other hand, of processes for increasing the supplies of the key hydrocarbons.

Although prediction of future trends in the oil industry must be hazardous, there is no question but that chemical manufacture will play an increasingly important role. In some instances there actually may be a reversal of the original position, i.e., the refinery may be utilizing by-products of the chemical factory, and not the factory the by-products of the refinery. In any case, a close relationship may be expected as the operations of both expand into new fields.

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Fuel Quality Requirements As Affected By Items of Motor Maintenance

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Phillips Petroleum Company

A NUMBER of items of motor maintenance, which exert an influence on fuel-quality requirements for trouble-free operation, are listed and discussed. Such items appear to fall logically into two classes, viz., those which contribute to place restrictions on the volatility characteristics of fuels, and those which contribute to determine required anti-knock characteristics.

A series of road tests on 18 cars is reported, in which the effects of various maintenance items on octane requirements were investigated. Average octane requirements of the cars, before and after the corrective measures and adjustments, were found to be 71.4 and 62.7 octane numbers, respectively, a decrease of 8.7 octane numbers. A reduction of 9 octane numbers was traceable to the removal of accumulated carbon deposits. The data show no definite relationship between octane-number-requirement decrease and miles driven since last carbon removal.

The magnitude of the effect of carbon deposits on octane requirements appears to warrant more attention on the part of car owners to applying the maintenance necessary to decrease a rapid buildup of deposits.

This paper was presented to Division of Refining, before Twenty-first Annual Meeting of the American Petroleum Institute, Chicago, November 15, 1940.

ITEMS of motor maintenance exerting an influence on fuel-quality requirements would appear to fall logically into two main classes, viz., those items which contribute to place limitations on the volatility characteristics of fuels, and those which contribute to determine required anti-knock characteristics. It is almost impossible definitely to classify some items of maintenance in this fashion, because they may have indirect effects on both volatility and anti-knock requirements. It is the purpose of this paper briefly to enumerate and describe some of the more important maintenance variables from a fuel-supplier's viewpoint.

Effects of such variables, of course, can be eliminated only by periodic checkups on the part of the car owner. Unfortunately, because of general dependability of our present-day automobiles—i.e., they frequently will continue to run regardless of how much they are abused—an owner seldom thinks of a checkup unless his car refuses to run at all. Then, when the checkup is made, it usually is limited to the particular gadget that is responsible for the immediate trouble, all others being completely ignored. If the car owner only knew and thoroughly appreciated that periodic checkups were intended to be made and that such inspections would result in material economies in operation, many of the problems of supplying him with real service, of guaranteeing him continued trouble-free operation throughout the life of his car, would disappear.

A Listing of Maintenance Variables

Variables affecting volatility requirements: Most of the maintenance items which bear upon the handling of fuels up to the inlet valves of the motor proper would fall into this classification. The chief items are those connected with the fuel pump, the carburetor, and the manifold.

Fuel pumps: Difficulties with the modern fuel pump, that affect volatility requirements, are usually a matter of proper adjustment of the discharge pressure.

Carburetors: Carburetors present a more complex problem, due to the wide variety of designs and the numerous adjustments. The carburetor details present in the maintenance picture include proper jet-size and metering-pin adjustments, proper adjustments of float level, idling, and automatic choke. The wide variety of designs makes it impossible to deal with each of these items individually. Suffice it to say that, individually and collectively, they contribute to determine the volatility characteristics of gasoline for trouble-free operation.

Manifolds: Manifold heat controls are the disturbing feature in this connection. In many instances units are found to be entirely inoperative or in poor adjustment after a period of service.

Other items: In addition to the items enumerated we also may include all of those other items which tend to cause high motor and under-hood temperatures, i.e., cooling-system deposits, excessively retarded spark, etc.

Variables affecting anti-knock requirements: The chief items which affect octane requirements are items dealing with the motor proper, i.e., condition of inlet and exhaust valves, condition of piston rings and cylinders, spark-plug condition, ignition timing, automatic spark-advance adjustments and, finally, combustion-chamber deposits. Other items, such as too rich automatic choke settings and cooling-system deposits, also contribute to a degree, either by giving directly higher temperatures in the combustion chamber or by speeding up the accumulation of troublesome deposits.

Maintenance As Affecting Octane Requirements

Because the advertised differences between gasolines offered at any one filling station are concentrated on octane number, other characteristics being ignored, it is natural when the customer makes his

TABLE 1

Effect of Various Engine-Maintenance Adjustments on Octane-Number Requirements of Several Cars

Car	Model (Year)	Standard Basic Spark Timing (Degrees)	Basic Spark Timing "As Received" (Degrees)	Octane-Number Requirement "As Received"	Change in Octane-Number Requirement Produced by: Adjusting Basic Spark Timing to Standard	Cleaning Carburetor Air Filter	Adjusting Distributor to Manufacturer's Specifications	Removal of Combustion Chamber Deposits	Grinding Valves	Final Octane-Number Requirement after Indicated Adjustments	Net Cumulative Change in Octane-Number Requirement	Miles Since Last Carbon Removal	Car Mileage
A-5	1938	4 BTC	8 BTC	79.1	— 1.9	.....	.....	— 13.6	.....	63.6	—15.5	28,500	28,500
B-1	1939	5 BTC	4.5 BTC	73.3	0.0	0.0	— 1.9	— 9.7	0.0	61.7	—11.6	31,452	31,452
B-2	1939	5 BTC	3 BTC	77.2	*	0.0	+ 1.9*	— 7.7	+ 1.9	73.3	— 3.9	6,668	35,400
B-5	1938	5 BTC	5 BTC	63.6	.....	+ 2.0	0.0	— 11.7†	0.0	53.9	— 9.7	9,155	50,140
B-6	1938	5 BTC	2 BTC	73.3	+ 7.4	— 1.6	— 1.9	— 7.4	0.0	69.8	— 3.5	23,514	36,612
C-1	1939	TDC	3 BTC	80.7	— 5.5	0.0	— 3.8	— 11.6	+ 5.8	65.6	—15.1	25,679	25,679
C-2	1939	TDC	6 BTC	91.5	—12.4	.....	.....	— 13.5	+ 3.8	69.4	—22.1	23,891	23,891
C-3	1939	TDC	6 BTC	77.2	— 7.8	+ 2.0	+ 9.3	— 1.6	—15.5	63.6	—13.6	18,357	18,357
C-4	1938	4 ATC	5 BTC	80.7	—11.2	0.0	0.0	— 7.8	+ 5.8	67.5	—13.2	26,788	26,788
C-6	1938	4 ATC	11 ATC	57.8	+19.4	0.0	0.0	— 15.5	+ 9.7	71.4	+13.6	39,234	39,234
	Average	.....	.....	75.5	.....	.....	.....	— 10.0	.....	66.0	.....	23,324	31,605

Note: Positive signs denote an octane-number-requirement increase. Negative signs denote an octane-number-requirement decrease.
* Adjustment of basic spark timing and distributor to manufacturer's specifications done in one step.
† New cylinder head installed.

purchases that he should think only of octane number and of things which bear upon his use of various octane-number gasolines. For this reason we are limiting our discussion from this point on to factors directly affecting the octane requirements of cars.

A study was made by the writers, in which an attempt was made to determine the magnitude of a few of the more important maintenance factors on anti-knock requirement. The study involved a total of eighteen 1938- and 1939-model cars in the popular

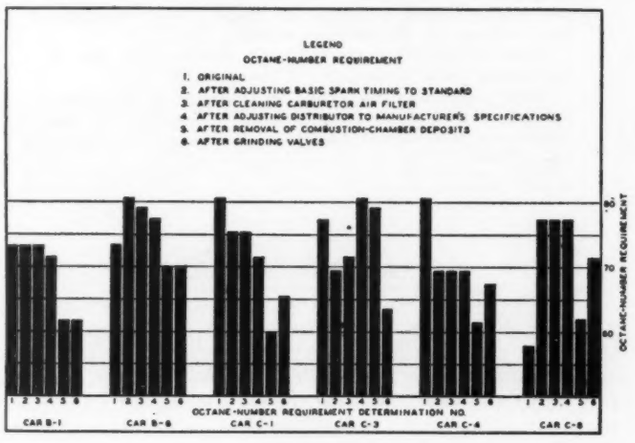

FIGURE 1

The Octane-Number Requirements of Six Cars After Performing Each of the Indicated Items of Maintenance.

big three low-price field. On 6 of these 18 cars the maintenance items studied included the following in the order named: 1, the effect of adjusting the basic spark timing to the manufacturer's specifications; 2, the effect of cleaning the air filter; 3, the effect of adjusting the distributor to the manufacturer's specifications; 4, the effect of removing combustion-chamber deposits; and, 5, the effect of grinding valves. On 4 of the remaining 12 cars most of these items of maintenance were investigated, and on 8 of them only the effect of carbon removal was determined.

Each of the cars first was checked carefully to determine octane requirements as received, in order to permit later comparisons as to the magnitude of the effects traceable to the various corrective steps. All maintenance operations and adjustments were handled by skilled garage service men.

Octane requirements were determined by the 1939 API Automotive Survey Committee road-test procedure. This procedure consists essentially of driving 30 to 50 miles at approximately 50 miles per hour to stabilize motor temperatures, then driving through the same cycles of operations involved in actually making the tests to obtain equilibrium temperatures, and finally making exploratory runs with various blends of A, C, and F reference fuels until the blend resulting in "trace knock" is found. The octane requirement assigned to the car in this test procedure is the ASTM octane number of the reference-fuel blend which results in "trace knock."

The data obtained for the six cars on which all of the indicated maintenance factors were studied are depicted graphically in Figure 1. These data also are shown in tabular form in Table 1, along with the 4 other cars on which most of the maintenance operations were performed. Inasmuch as these data indicated that the item of combustion-chamber deposits was of major importance, further observations were made on the effect of this variable in 8 additional cars. The effect of carbon removal on all 18 cars is shown in Table 2. Compression pressures were obtained for some of these cars, both before and

[*Continued on page 122*]

TABLE 2

Effect of Carbon Removal on Octane-Number Requirement

CAR	Model (Year)	Octane-Number Requirement Before	Octane-Number Requirement After	Decrease in Octane-Number Requirement	Miles Since Last Carbon Removal
A-1.....	1939	57.8	52.0	5.8	3,163
A-2.....	1939	61.7	48.1	13.6	24,124
A-3.....	1939	69.4	61.7	7.7	37,232
A-4.....	1938	61.7	59.8	1.9	36,956
A-5.....	1938	77.2	63.6	13.6	28,500
A-6.....	1938	65 6	59.8	5.8	45,322
B-1.....	1939	71.4	61.7	9.7	31,452
B-2.....	1939	79.1	71.4	7.7	6,668
B-3.....	1939	67.5	61.7	5.8	28,722
B-4.....	1938	75.2	61.7	13.5	15,906
B-5.....	1938	65.6	53.9*	11.7	9,155
B-6.....	1938	80.7	73.3	7.4	23,514
C-1.....	1939	71.4	59.8	11.6	25,679
C-2.....	1939	79.1	65.6	13.5	23,891
C-3.....	1939	80.7	79.1	1.6	18,357
C-4.....	1938	77.2	69.4	7.8	26,788
C-5.....	1938	71.4	63.6	7.8	4,915
C-6.....	1938	77.2	61.7	15 5	39,234
Average of all cars		71.7	62.7	9.0	23,865
Av. of 1939 cars..		70.9	62.3	8.6	22,145
Av. of 1938 cars..		72.5	63.1	9.4	25,588

*New cylinder head installed.

Heavy-Duty Motor Oils

By H. C. MOUGEY
General Motors Corporation

THE name "heavy-duty," as applied to lubricants, is tentative. The American Petroleum Institute has a committee which is studying this subject; and when this committee makes its suggestion as to the name by which these lubricants should be known, I feel sure that the name this committee proposes will be adopted by the automotive industry. In the meantime the tentative name "heavy-duty" is being used.

The story of heavy-duty lubricants is the story of progress. The oil and automotive industries constitute a kind of Siamese twins, and the well being of each industry very closely is bound up with that of the other. The cost of an automobile, and the cost of petroleum products to operate the automobile during its expected life, are approximately the same, and progress in one industry depends to a very large degree on progress in the other industry.

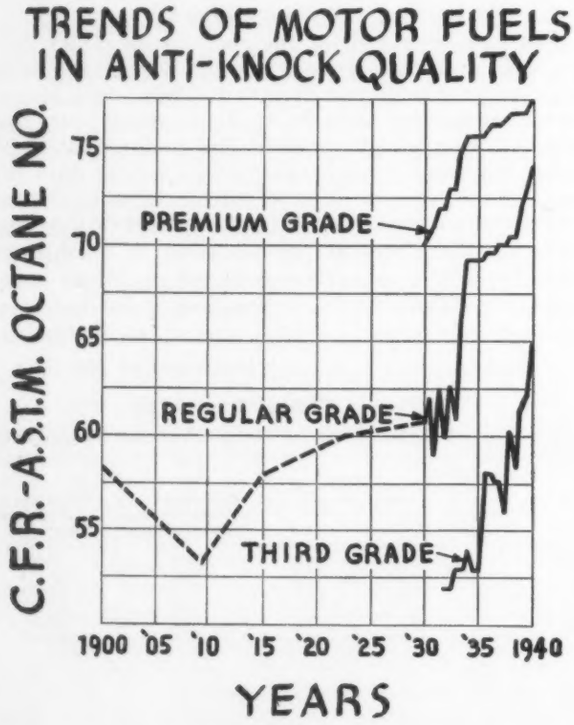

FIGURE 1
Trend in Anti-knock Quality of Motor Fuels.

Data from "Trends in the Properties of Volatile Liquid Fuels," by D. P. Barnard and A. H. Fox, Standard Oil Company (Indiana), symposium on "New Materials in Transportation," Detroit spring meeting, American Society for Testing Materials, March 6, 1940, and from "Better Fuels for Better Engines," by William H. Hubner, Ethyl Gasoline Corporation, *SAE J.* 47 [4] Oct. (1940).

WITH improvements in engines, fuels and roads, the service requirements on gasoline and Diesel engines are increasing rapidly. This means that the lubricating oils should be able to lubricate the engines under the heavy-duty service conditions that are becoming more common.

In order to meet these requirements, the lubricating oils should be resistant to oxidation or chemical decomposition in the crankcase; the oil must not be corrosive to engine parts; the products of thermal decomposition in the combustion chamber should not be excessive; and the oil should be of such a nature that the decomposition products that get into the oil will not adhere too strongly to pistons, rings, or other engine parts.

Oils and fuels are just as much parts of the engine as pistons and crankshafts. Progress in engines and progress in oils and fuels must go hand in hand, and neither the oil nor automotive industry can make much progress by itself, or if progress lags behind in the other industry.

These desirable results can be obtained by the oil and automotive industries at the present time.

This paper was presented to Division of Refining, before the Twenty-first Annual Meeting of the American Petroleum Institute, Chicago, November 14, 1940.

Octane-Number Trend

During the last few years progress in refining gasoline has been very rapid. The trends in octane rating of gasoline are shown in Figure 1. In the very early days "octane" rating of fuels was unknown. As the demands for gasoline increased, more and more higher-boiling low-octane fractions were included in the gasoline, until about 1910—when the trend became reversed due to the fact that the increased use of cracking provided larger amounts of fractions with somewhat higher octane rating. With the more general use of lead in regular gasoline, about 1933, the octane value rose rapidly. It then remained fairly stationary for several years, until competition caused a number of companies to increase the octane rating of their gasolines—and this higher level is now the rule rather than the exception. Unless this trend is changed by the war, or by legislation, or by some other factor, it appears that the industry will try to consolidate its position at this general level for two or three years, at which time the shape of the curve indicates that a further increase in octane value may take place.

While this progress was being made, the automotive industry has followed the petroleum industry in developing automobiles that will use these gasolines to the best advantage. In this work improvements in automobile engines have followed, and not preceded,

the development in fuels, as obviously it is impossible for the automotive industry to market automobiles in large numbers unless the fuel to operate these automobiles is available.

Automobile-Manufacturing Trend

Figure 2 shows the very great change in one automobile company's product in the period from 1909 to 1941. This same kind of a change, in more recent years and as an average for the entire automotive industry, is shown in Figures 3 and 4. In Figure 5 it will be noted that up to 1929 the problem of production was very great, but during the last 11 years we have not quite reached 1929 production; and when we study the curves in Figures 3, 4, and 5, it is apparent that production problems are not as great as they were formerly, and the real problem in recent years has been to produce better cars for less money.

Diesel Trend

In the Diesel industry progress is taking place at a very rapid rate. According to an advertisement that appeared in *Diesel Progress* in April, 1938, a 3000-horsepower Diesel engine of 1926 weighed 801,000 pounds or 267 pounds per horsepower. In 1938, 12 years later, for an engine of the same power the weight

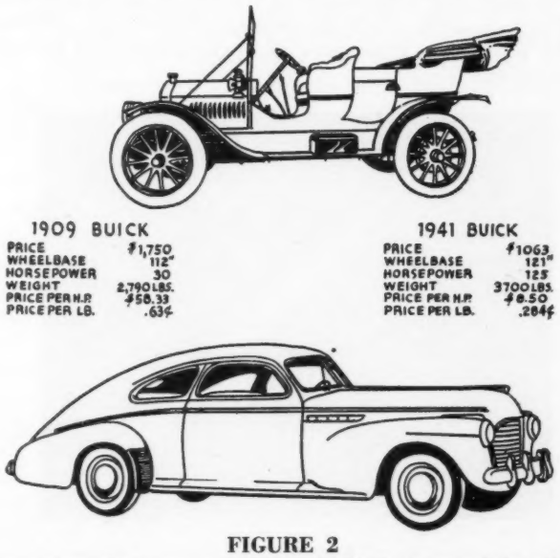

FIGURE 2
Comparison between a 1909 and 1941 Automobile (Data from General Motors Research Technical Data Department).

was only one tenth as much, or 25 pounds per horsepower. At the time this advertisement appeared, streamline Diesel passenger trains already had been in service for several years. The first streamline passenger train started in service in 1934. The engine developed 660 horsepower and weighed 20 pounds per horsepower. This train is still in service. It now is operating between St. Louis, Missouri, and Burlington, Iowa. This train long ago passed the million-mile mark, and streamline passenger trains now are so common that it is difficult to write a news item about them.

In the railroad Diesel industry the introduction of Diesel engines for main-line freight trains is the most important recent development. The first freight Diesel for main-line service started operation this year. The Diesel engines in this locomotive develop 5400 horsepower, and weigh 124,000 pounds. This is 23 pounds per horsepower, based on the engines, without taking into account the weight of other parts of the locomotive. Of course, the extra power required for the auxiliaries is in addition to the 5400 horsepower which is delivered to the generators.

At the same time the Diesel advertisement previously mentioned appeared in the magazine, the factory for manufacturing the General Motors model 71 Diesel started in production. These engines are

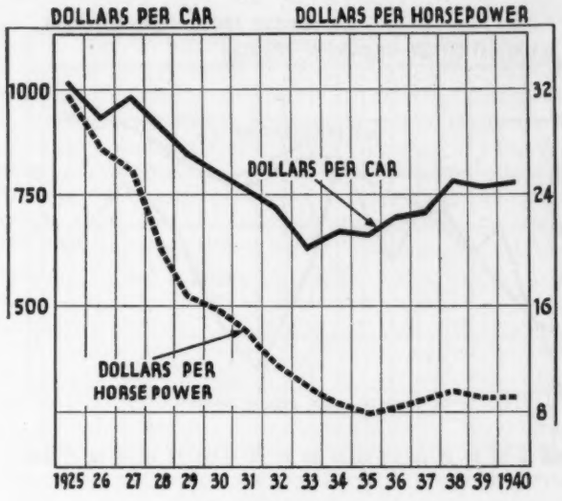

FIGURE 3
Trend in Costs of Automobiles (Data from *Automobile Facts and Figures*, 1940).

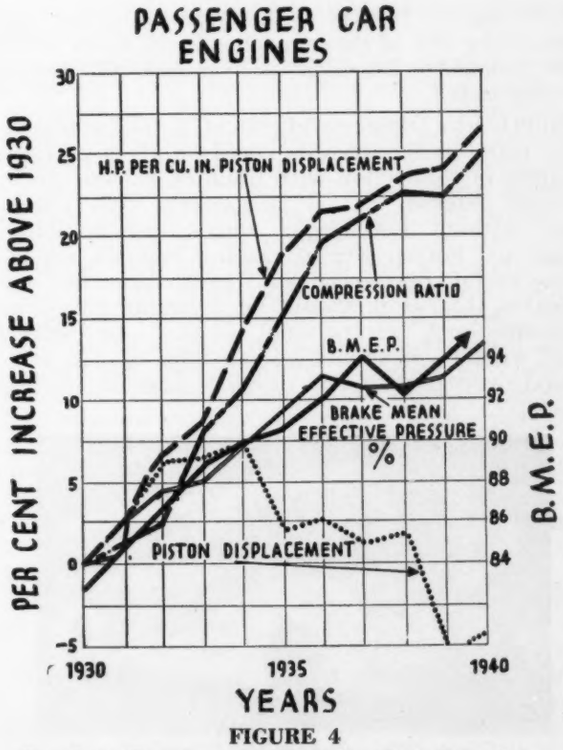

FIGURE 4
Trends in Passenger-Car Engines (Data from Same Sources as Figure 1).

small enough to be used in trucks and coaches. The 6-cylinder engine develops 165 horsepower, and weighs 1650 pounds, or 10 pounds per horsepower, without the use of light-weight alloys except in the blower. Figure 6 shows a coach powered with one of these engines. This coach, one of a fleet of 21, operates over one of four sections of the route between Chicago and the Pacific Coast. The mileage

covered by the fleet since delivery in June, 1939, is so large as to average for each coach nearly half a mile per minute (26.5 miles per hour), counting no time out whatever, day or night. The present operating schedule is about 20,000 miles per month for each coach. Coaches using this engine are now in use in both city and inter-city service. It is interesting

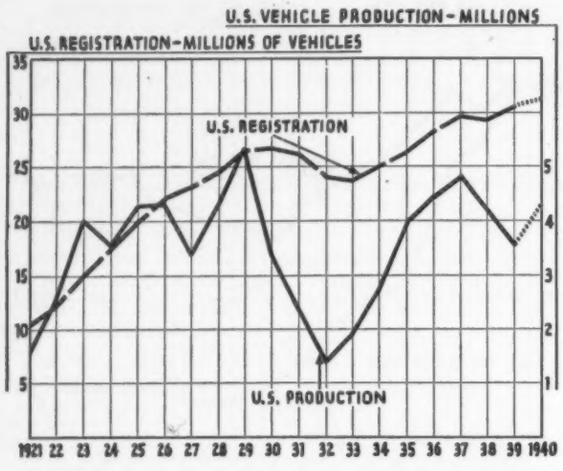

FIGURE 5
Automobile Registration and Production (Data from *Automobile Facts and Figures*, 1940).

to note that on July 15 of this year the actual miles operated by 594 of these coaches in 27 fleets totaled more than 40,000,000 miles, an average of 67,000 miles for each coach.

Progress in Diesel development is continuing at a rapid rate. Similar records could be given of Diesel progress in connection with tractors, marine service, national defense, etc. It is apparent that Diesels, made without low-weight alloys, and similar in weight per horsepower to gasoline engines, are now in successful commercial use. However, recent work indicates that, if it should be desirable for special purposes—such as national defense—to decrease these weights, it should be possible, by the use of special construction, to develop Diesels of large power output with weights as low as 3 pounds per horsepower.

FIGURE 6
Diesel-powered Motor Coach.

Lubricating oils have severe service conditions to meet nowadays. This Diesel-powered motor coach, one of a fleet of 21, operates over one of four sections of the route between Chicago and the Pacific Coast. The mileage covered by the fleet since delivery in June, 1939, is so large as to average for each coach nearly half a mile per minute (26.5 miles per hour) counting no time out whatever, day or night. The present operating schedule is about 20,000 miles per month for each coach. (Photograph, courtesy Yellow Truck and Coach Manufacturing Company.)

Road Progress

In discussing progress in the oil and automotive industries, progress in roads must be considered. This progress is just as spectacular; but because roads extend over such great distances, it is harder to visualize the progress that is being made. However, every year enough outstanding developments occur so that we continually are being thrilled by these achievements. The most recent of these is the completion of the Pennsylvania Turnpike, which provides for safe high-speed travel between Pittsburgh and Harrisburg (Figure 7).

Lubricating-Oil Evolution

When we contemplate the progress that has been made in fuels, in automobiles, and in roads, the questions naturally arise: "What has been done to make lubricating oil more suitable for heavy-duty service in modern engines"?; and "what changes, if any, are desirable"?

In the minds of the general public, the quality of any product usually is associated with its cost. In the case of lubricating oil, this is not necessarily true. The only real measure of quality of a lubricating oil is its performance in service, and this depends as much upon the suitability of the oil as upon its composition or cost. A high-quality oil for any service is one that gives good results in the particular service in question.

FIGURE 7
Section from Pennsylvania Turnpike (Photograph from Wide World Photos, Inc.).

Some of the things the oil industry already has done in improving lubricants are:

1. Oils with low pour points (to improve pumping of the oil at low temperatures).
2. Oils to improve starting in cold weather (10-W and 20-W).
3. Oils with less change in viscosity with change in temperature (high viscosity index).
4. Oils with improved anti-friction properties (oiliness, extreme-pressure oils, hypoid lubricants, etc.).
5. Oils with less-easily oxidized sludge-forming materials (improved refining, including solvent refining).
6. Oils for "heavy duty" (not all oil companies now make such oils).

Additional Heavy-Duty Properties

We recently made a series of tests to determine

what additional properties oils should have for heavy duty. A General Motors model 71 Diesel was operated for test purposes at full load and full speed without a filter, using a Mid-Continent conventionally-refined SAE 30 oil. The tests showed that the oil increased, with use, in acid and in chloroform solubles; and that the rate of increase was much higher with 235 to 240° F. crankcase oil than with 185 to 200° F. oil; but the increase in "carbon," or "chloroform-insoluble material," was not affected by crankcase-oil temperature—at least until after the oil in the crankcase had become oxidized very badly. This indicated that the increase in acid and chloroform solubles was the result of oxidation in the crankcase, and the "carbon" in the crankcase oil in these tests was the result of thermal decomposition of oil in the combustion chamber—with part of these decomposition products escaping through the exhaust, and part working down past the pistons and getting into the crankcase oil.

If the engine was operated for a long time under heavy-duty conditions on this straight mineral oil without using a filter, the oil in the crankcase oxidized, and the oil that got up into the combustion chamber thermally was decomposed, and the resulting decomposition products in the oil caused trouble.

1. Increase of acid caused bearing corrosion.
2. Increase in oil-insoluble products plugged oil passages and interfered with the supply of oil to surfaces which should have been lubricated.
3. Increase in oil-insoluble products plugged air ports, interfering with combustion, or they stuck on the pistons or piston skirts, causing ring sticking or scuffing of the pistons.

When we operated the engine on the straight mineral oil with small filters which mechanically removed some of the oil-insoluble materials, the troubles due to these insoluble materials were decreased—depending upon the efficiency of the filters and the frequency with which the filter elements were changed.

An Ideal Oil

When we operated the engine on the straight mineral oil with very thorough filtering, using large fuller's-earth filters, none of the foregoing troubles occurred, and the engine could be operated for many hundreds of hours without change of oil and with no appreciable effect on either the oil, pistons, rings, or bearings. This amount of filtering, however, was much more than we could expect in normal use of the engine.

These tests indicated clearly that an ideal oil should not oxidize in the crankcase, so that no acid or sludge or other oxidation products would be formed in the crankcase; and it should not form deposits by thermal decomposition in the combustion chamber, which would work past the piston and plug the ring grooves, adhere to the piston or other engine surfaces, or contaminate the crankcase oil and interfere with oil distribution to the surfaces requiring lubrication. If this ideal oil is not possible, then very complete removal of the decomposition products with a suitable filter would solve the problem. If this cannot be done commercially, then another solution might be a special oil. Such an oil would be made from a suitable type of crude and so refined that:

1. It would not form undesirable deposits by thermal decomposition in the combustion chamber.
2. It would not contain objectionable amounts of easily-oxidized sludge-forming materials.
3. It would not corrode bearings nor oxidize in the crankcase, forming corrosive acids or objectionable amounts of insoluble oxidation products.
4. It would have the property of preventing any soot or carbon or other decomposition products from sticking to the surfaces of the engine parts. This property is called "detergency."

Oxidation Resistance and Detergency

If such an oil could be obtained, and if it were used with a judicious combination of filtering and draining to prevent an undue accumulation of decomposition products, it should give very satisfactory results in heavy-duty service with either gasoline engines or Diesels, or both. However, inasmuch as gasoline engines in general operate at higher speeds than Diesels, with resulting higher crankcase-oil temperatures, and as Diesels in general are likely to form more products of incomplete combustion in the combustion chamber, it is apparent that the best oil for heavy-duty service in gasoline engines will stress resistance to oxidation in the crankcase, and for service in Diesel engines the emphasis will be on detergency. As gasoline engines and Diesel engines differ among themselves in regard to crankcase-oil temperature under heavy-duty service conditions, and in regard to the amounts of decomposition products which form in the combustion chamber and tend to work down past the pistons, it is apparent that different models of Diesels or gasoline engines will vary in the way they stress oxidation resistance and detergency.

For example, a Diesel which had corrosion-resistant bearings, and which operated with low crankcase-oil temperature but with high ring-belt temperature, would stress detergency and freedom from the formation of carbon by thermal decomposition in the combustion chamber, with not much importance attached to resistance to oxidation. It probably would be easier to make an oil especially suited for such a Diesel by using low to medium viscosity-index (VI) stocks. On the other hand, a Diesel with just the reverse in these characteristics would stress resistance to oxidation, with much less importance attached to detergency, and it would probably be easier to make an oil especially suited for such a Diesel by using medium or high VI stocks. There might be this same kind of difference between gasoline engines. However, by properly combining detergency, resistance to oxidation, and freedom from thermal decomposition, it would be possible to make a single oil that would be highly satisfactory in all kinds of Diesels or gasoline engines, or both.

In this reference to the use of different VI-base oils, it should be emphasized that these properties are not due to the VI of the oil, nor to its gravity, or color, or other similar properties, but to such properties as its solvent power, its thermal-decomposition products, and to the difficulty of removing easily-oxidizable sludge-forming materials by refining.

Crankcase-Oil Temperatures

In this discussion the subject of high temperatures has been mentioned. According to the fundamental laws that apply to the development of mechanical power from thermal energy, the efficiency of any engine depends upon the difference between the highest temperature at which the working fluid is used and the lower temperature at which this working fluid is exhausted. This means that the trend of temperature level in engines will continue to be

high; and as automotive engineers learn of ways in which temperatures of any particular parts of the engine can be lowered, the tendency will be to take advantage of such a possibility by increasing the power and efficiency of the engine, rather than by actually lowering the temperature. Progress in this direction should not be handicapped by any failure of the oil industry to make available lubricants that will operate at as high temperature levels as possible.

In considering crankcase-oil temperatures it must be remembered that engines do not always operate under heavy-duty service conditions. Door-to-door milk delivery is an example of very light service in which crankcase-oil temperatures are like to be low, and in the winter trouble due to condensation of water in the crankcase may be experienced. Almost any passenger automobile may be subject to operation for longer or shorter periods of time in other similarly light service. In trying to overcome trouble due to condensation of water in the crankcase, the methods that have given the best results are:

1. Frequent draining, to remove the condensed water along with the crankcase oil.
2. Preventing the condensation of water in the crankcase by keeping the cooling liquid warm (thermostats).
3. Removing the condensed water from the crankcase oil (ventilation, with high enough crankcase-oil temperature to make the ventilation effective).

This means that automobile engineers must see to it that the crankcase oil warms up very rapidly to a minimum temperature, and this factor also tends toward a set of conditions wherein high crankcase-oil temperature under heavy-duty service may result, even though engineers recognize that anything they can do to decrease maximum crankcase-oil temperatures greatly will decrease the troubles likely to be experienced in heavy-duty operation.

Testing Heavy-Duty Oils

After the problem of making heavy-duty oils is understood thoroughly and methods of solving the problem are known, the next problem is the testing of such oils; for without test methods it is impossible to develop the oils or to tell how nearly satisfactory the oils are after they have been developed. Unfortunately, there are no standardized chemical laboratory tests by which we can predict the performance of oils under heavy-duty service—although certain tests, such as the Underwood test, are very valuable in this work. The final measure of quality always must remain "performance in service." However, it is possible to make engine tests under controlled conditions; and, from the results of these engine tests, very good predictions as to performance in the various kinds of service can be made.

It may be objected that engine tests consume too much time and money, but this same principle of service testing under controlled conditions is the standard method of testing in many lines of endeavor. For example, the official method of mushroom testing is:

> "To test a mushroom, simply eat
> The specimen you chance to meet,
> And note, next day, with studious care,
> If you've stayed here or gone elsewhere."

In testing oils in our laboratory we have standardized on two tests, one using a Chevrolet engine and one using a model 71 General Motors Diesel engine. The Chevrolet engine test, in the manner in which we conduct it, stresses resistance to oxidation of the crankcase oil. The model 71 General Motors Diesel test stresses both detergency and resistance to oxidation. On request, we shall be glad to send full details in regard to these tests to anyone who is interested; but, briefly, the test conditions are as shown in Table 1. Of course, these conditions are chosen for test purposes, to develop the weaknesses of the oils being tested; and these test conditions are not recommended for regular operation in service.

Oxidation Inhibitors

The oil industry is familiar with the problems connected with the development of oils which have the special properties required for heavy-duty oils, but until recently it has not tried to combine all these properties in a single oil. Several years ago when copper-lead and cadmium bearings first came into use in large production, the oil industry was faced with the problem of making oils resistant to the development of acid. If the oils were refined to such an extent that the easily-oxidized sludge-forming materials were removed, the natural oxidation inhibitors which prevent oxidation of the oil with formation of acid usually were removed also, at least to a great extent. To correct this deficiency, oxidation inhibitors were added—and thus this problem was solved.

Other Desirable Properties

Several years later, when the problem of special Diesel oils became acute, it was found that, by the addition to suitable base oils of materials called detergents, the difficulties due to decomposition of oil in the combustion chamber and at the ring belt could be overcome. However, this development was made on a test schedule with babbitt bearings and with a

TABLE 1
Laboratory Tests

	Chevrolet Engine Test	Model 71 General Motors Diesel-Engine Test		
		3-Cylinder	4-Cylinder	6-Cylinder
Revolutions per minute	3,150	2,000	2,000	2,000
Equivalent miles per hour	60	.....	.....	.....
Load, brake horsepower	30	80	106	160
Water (out), deg. F	200	180	180	180
Crankcase oil, deg. F	280	230	230	230
Oil consumption (approximate value)	500 miles per quart	0.20 lb. per hour	0.27 lb. per hour	0.40 lb. per hour
Miles per quart (calculated for 60 mph)	500	570	422	285
Length of test, hours	67	500	500	500
Length of test (calculated miles for 60 mph)	4,000	30,000	30,000	30,000
Bearings	Babbitt (with 1 copper-lead)	Copper-lead	Copper-lead	Copper-lead
Filters	None	*	*	*
Oil change during test	None	None	None	None

* Filters are not used for the first 144 hours (8,640 miles) in order to learn as much as possible about the rate of increase of oil-decomposition products. The regular filter equipment is used during the remainder of the test (356 hours, 21,360 miles).

crankcase-oil temperature of approximately 130° F., and with an oil-drain period of 60 hours. With such a schedule, oxidation resistance and stability of the base oil were not very important and, consequently, many of the oils originally developed on this schedule were unsuited for use in engines with alloy bearings, or with higher crankcase-oil temperatures, or for use when longer oil-drain periods were desired. However, the oil industry recently has learned how to make oils which have all of these desirable properties, and such heavy-duty oils are now in rather wide distribution.

Bearing Corrosion

In any discussion of heavy-duty oils, the subject of bearing corrosion always comes up. In any service, bearings should not fail from any cause. This includes failing due to poor anti-friction properties, poor resistance to fatigue, or poor resistance to corrosion. When babbitt will produce bearings of suitable resistance to fatigue, it is probable that it will continue to be used, due to its good anti-friction and resistance to corrosion. When babbitt is not good enough in resistance to fatigue, the logical answer at present is to use cadmium or copper lead, and to avoid corrosion trouble by using oils which will not form acids nor cause corrosion under service conditions.

FIGURE 8
Cross-section from High-Tin Babbitt Bearing (Magnification 100×).

Tin, 84.08 percent; copper, 7.88 percent; antimony, 7.29 percent; lead, 0.75 percent. The dark areas are high tin. The white crystals are various hard compounds of tin, copper and antimony.

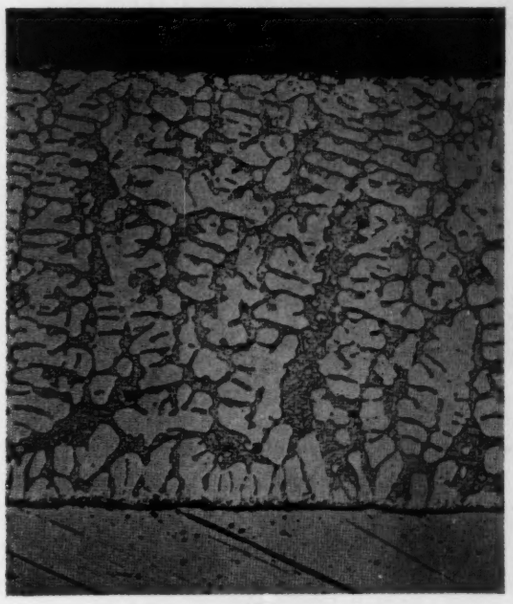

FIGURE 9
Cross-section from Conventional Copper-Lead Bearing (Magnification 100×).

Copper, 60 percent; lead, 40 percent. The light-colored area at the base of the picture is a part of the steel back. The white crystals are practically pure lead. The edge at the black portion of the picture is the bearing surface.

There recently have been introduced new bearings which may solve this corrosion problem without sacrifice of the desirable properties of anti-friction and resistance to corrosion. The new main bearings in use in the 1941 Buick are a type of bearing that gives them the anti-friction and corrosion-resistant properties of babbitt with a very high resistance to fatigue. Babbitt is a corrosion-resistant material composed of a rather soft and weak matrix, which has its fatigue resistance increased by the inclusion of certain hard and strong crystals. Copper lead is largely the reverse. It is a hard and strong matrix, which has its anti-friction properties increased by the inclusion of lead, but the lead is subject to corrosion. The new Buick main bearings are fundamentally similar in structure to copper-lead bearings. They have a hard and strong matrix firmly bonded to the steel backing, with the anti-friction properties of the bearing increased by the inclusion of corrosion-resistant high-lead babbitt (see Figures 8 to 11, inclusive).

If service tests now under way indicate that corrosion-resistant bearings with other suitable properties, such as anti-friction, resistance to fatigue, etc., can be produced commercially, it is evident that such bearings will solve the corrosion problem. However, it must be emphasized that millions of engines with copper-lead or cadmium bearings are now on the roads, and these engines will continue to require lubrication for a number of years. This means that, regardless of any progress which the automotive industry makes in development of corrosion-resistant bearings, the oil industry should not think that this relieves it of the necessity of producing oils which will not oxidize nor corrode bearings.

Oxidation in poorly refined oils produces oil-insoluble sludge, and oxidation in highly refined oils produces oil-soluble oxidation products which may be precipitated in the form of sludge when fresh oil is added, either to maintain the oil level or when the crankcase oil is drained and the fresh oil is added to the oil which remains in the engine. It was believed formerly that "coffee grounds" were produced by chunks of carbon dropping from the under side of hot pistons, but it is known now that most of the coffee grounds in crankcase oil are the result of adding fresh oil which precipitates insoluble deposits from the oil-soluble material in oxidized oil in the crankcase. Further heating of these insoluble deposits, even at normal crankcase-oil temperature, soon changes them to the familiar hard and insoluble coffee grounds.

The only commercial solution to this problem is to prevent the oxidation of the crankcase oil in service in the engine.

Piston Problems

It cannot be emphasized too strongly that the real problem in producing heavy-duty lubricants is in connection with the pistons, and not with the bearings. If this were not so, there would be no problem of heavy-duty lubricants for engines with babbitt bearings. Even though, as a result of intensive work by the automotive industry on corrosion-resistant bearings, such bearings finally should be in universal use, as long as engines of the present types are made we shall have pistons; and, in order to provide these pistons with proper lubrication, the oil industry should be able to supply oils that will not oxidize in the crankcase, with the formation of sludge, coffee grounds, and varnish—and the oil should be of such a nature that the products of thermal decomposition, which originate in the combustion chamber, will not adhere to rings, pistons, or other engine parts.

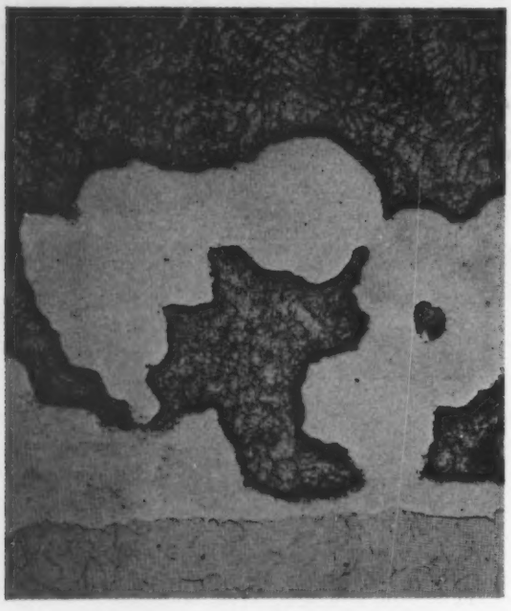

FIGURE 10
Buick-Type Composite Bearing
(Magnification 100×).

The light-colored area at the base of the picture is a part of the steel back. The white areas are copper-nickel hard matrix, bonded by fusion to the steel back. The dark areas are corrosion-resistant lead-base babbitt. This babbitt is put into the bearing after the copper-nickel matrix has been fused to the steel back; and the babbitt thickness can be varied at will, giving a thin over-lay of babbitt, bonded both mechanically and by fusion to the copper-nickel matrix. In the Buick main bearings this over-lay is only a very few thousandths of an inch thick.

Summary of Tests

As illustrations of the kind of results that can be obtained at the present time in both gasoline and Diesel engines under different operating conditions and with different types of oils and addition agents, some of the data from engine tests may be of interest. Except as noted, the tests were made on the test schedules shown in Table 1. In the tests on oil for gasoline engines, Chevrolet engines were used. In the tests on oils for Diesels, model 71 General Motors Diesel engines were used. These tests may be summarized as shown in Tables 2 to 6, inclusive.

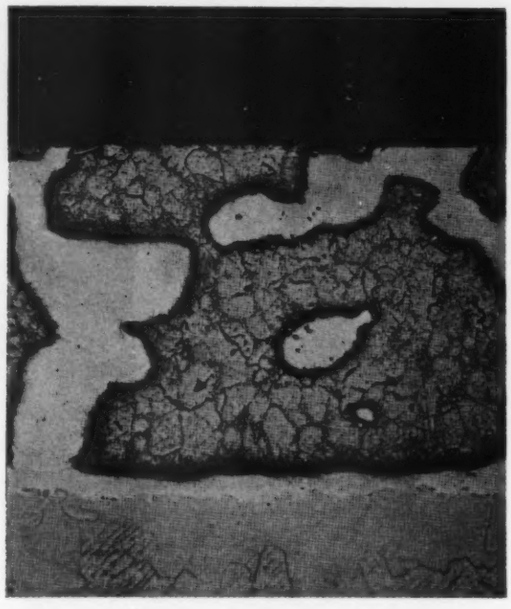

FIGURE 11
Experimental "Synthetic Copper-Lead" Bearings
(Magnification 100×).

The structure of this bearing is similar to that described in Figure 10. The bearing surface is obtained by removing the over-lay of babbitt—giving a bearing surface of hard copper-nickel for strength and resistance to fatigue, and a soft surface of high corrosion-resistant babbitt for anti-friction properties. The bearing surface has a 40-percent area of copper-nickel and a 60-percent area of babbitt.

Effect of Decomposition Products Originating in the Combustion Chamber in a Gasoline Engine

A series of four runs was made to throw light on the problem of decomposition products originating in the combustion chamber. The oil used was a highly refined 20-W Pennsylvania-base oil. The pertinent data in regard to the operating conditions are shown

[*Continued on page 120*]

TABLE 2
Summary of Tests

Run No.	Crankcase-Oil Temperature (Deg. F.)	Jacket-Water Temperature (Deg. F.)	Speed (RPM)	Temperature of Underside Piston Crown (Deg. F.)	Remarks
1A.....	280	200	3,150	500–510	Regular run, load to maintain piston temperature constant (about 25 hp.)
2A.....	280	200	3,150	300–315	Engine motored, gasoline line disconnected, throttle closed. High combustion-chamber temperature due to heat of compression.
3A.....	280	200	3,150	275–280	Same as run 2A, except exhaust valves cut off to avoid compression of air in combustion chamber.
4A.....	280	200	3,150	275–280	Same as run 3A, except 0.50 per cent inhibitor *X* and 0.50 per cent inhibitor *Z* added to crankcase oil.

Viscosity Classification of Lubricants

By W. S. JAMES
The Studebaker Corporation

This paper was presented to Division of Refining, before Twenty-first Annual Meeting of the American Petroleum Institute, Chicago, November 14, 1940.

THE ASTM viscosity-temperature chart is the most convenient means by which the viscosity characteristics of oils can be presented and compared. In an effort to compare the several ranges of motor oils outlined by the SAE viscosity classification, the plot shown in Figure 1 is obtained. In this chart the lines outlining the limits of the several groups are drawn for oils of 100 and zero viscosity index (VI). The overlapping areas of the chart are shaded. The result is confusing, and may be one of the reasons that the full value of a viscosity classification never has been realized. Anyone starting to make such a chart as an aid to making practical use of the SAE classification either would never finish it, or would turn to some other means to help solve the particular problem in mind.

A similar plot of the SAE classification for transmission and rear-axle lubricants is shown in Figure 2. This plot is understandable and usable. All lubricants falling below the solid line are classified as SAE 80. All lubricants falling within the hour-glass-shaped area, outlined by the lines of small circles, are SAE 90. All lubricants falling between the line of crosses are SAE 140, and all lubricants falling above the higher line of crosses are SAE 250.

As an illustration of one way in which this chart can be used, experimental values are plotted of the "leveling-off" temperatures with transmission lubricants of differing viscosities. These points are shown by heavy capital **Ts.** These runs were made at an air temperature of 60° F. on two different days; and, as the slope of the lines on successive days were about parallel, the average line was drawn as shown. The tests were made on a car with a transmission of the conventional type at 60-miles-per-hour road load. If it is assumed that the leveling-off tempera-

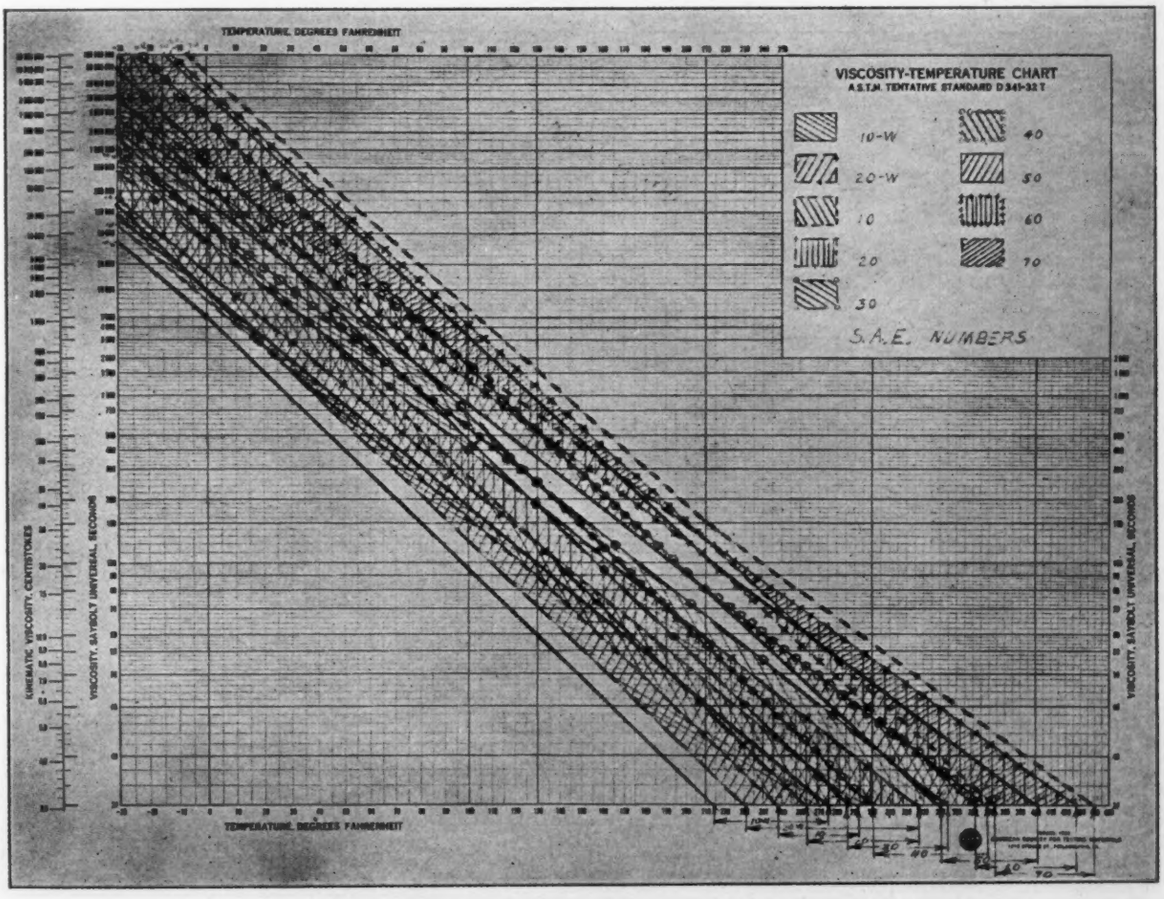

FIGURE 1

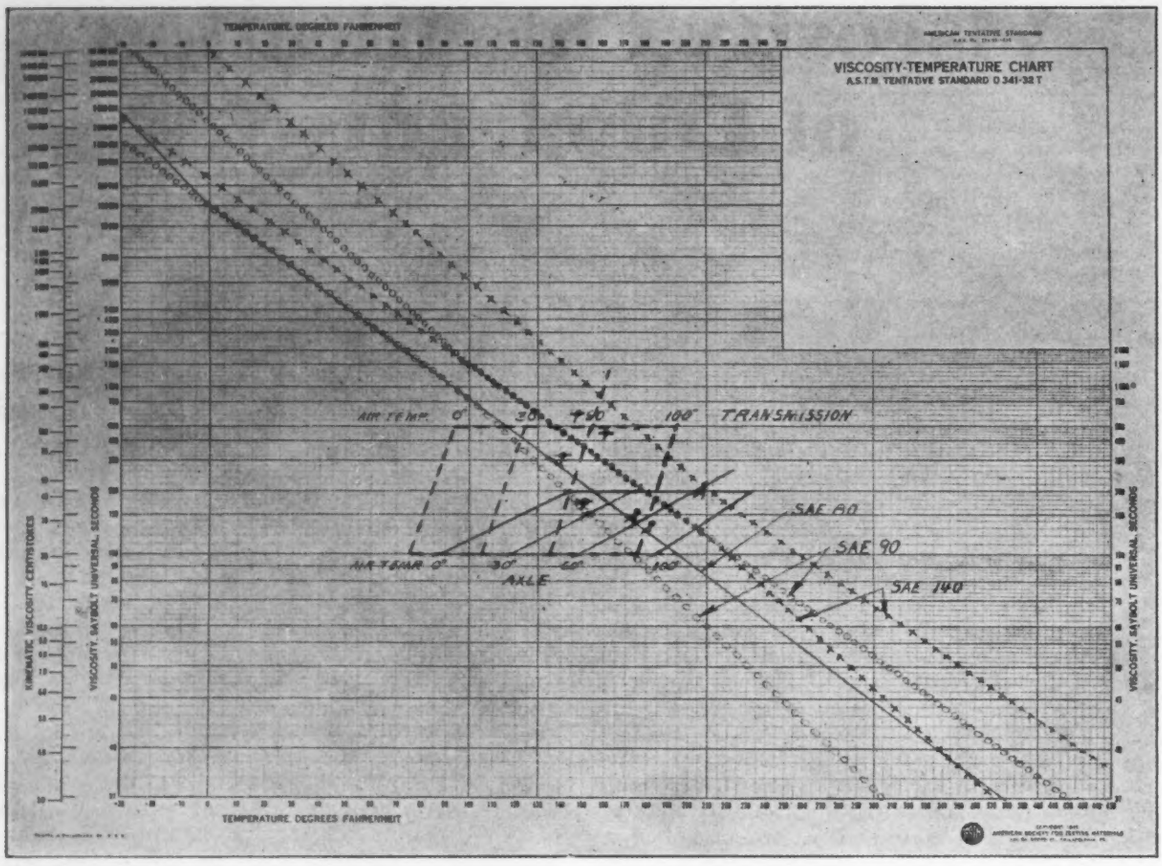

FIGURE 2

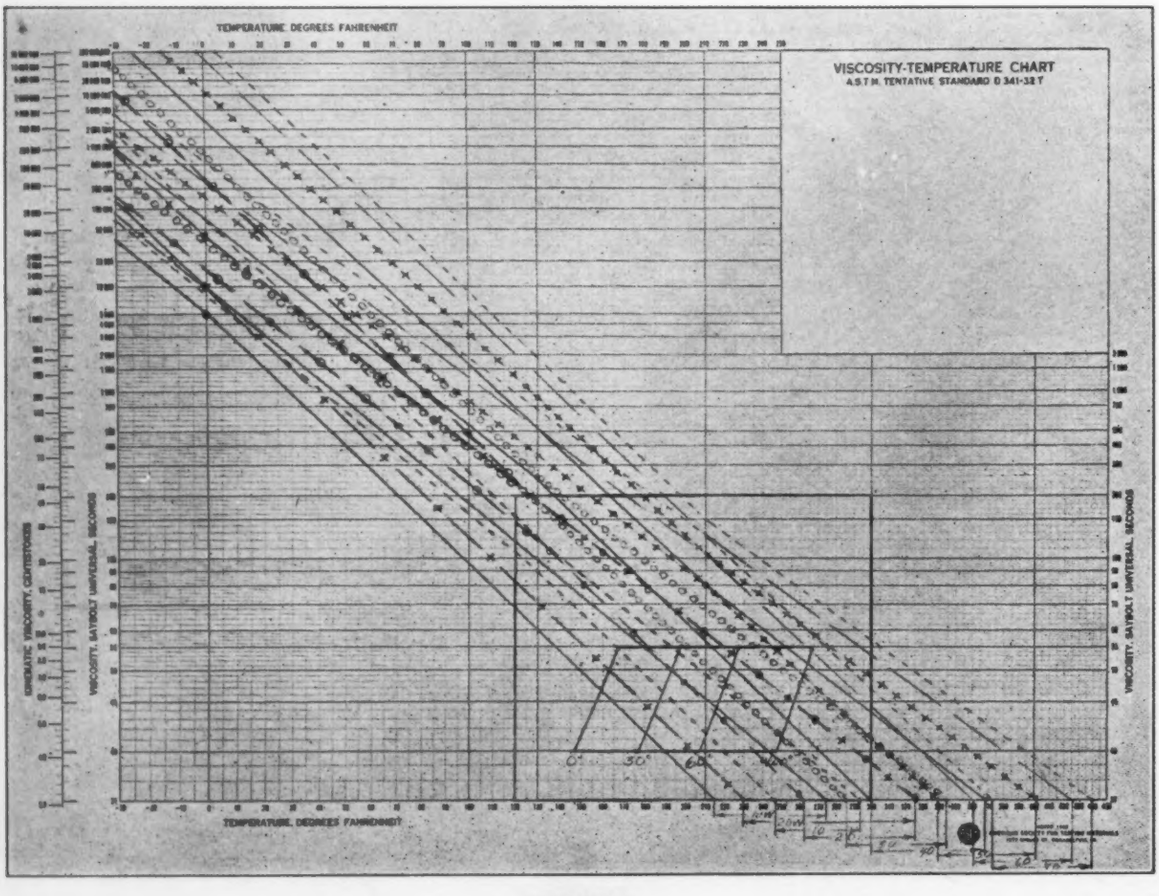

FIGURE 3

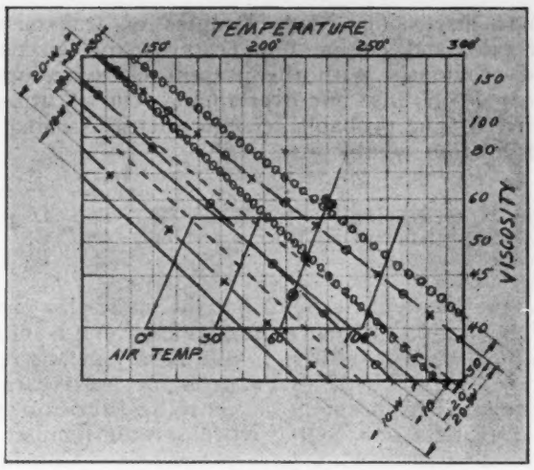

FIGURE 4

ture varies directly with the outside air temperature, similar lines for other air temperatures can be drawn parallel to the 60°-F. line. Such lines are shown for 0, 30, and 100° F. There may be some question as to the correctness of the assumption that the lubricant temperature varies directly with the outside air temperature, but it will suffice for the purpose of illustration. If the transmission maker desired to use lubricants which, as far as possible, would have Saybolt viscosities not less than 100 sec and not greater than 500 sec, the area in which he would like to have his transmission operate under these conditions of speed and load would be shown by the dotted lines. A quick examination of the chart would show that an SAE 90 would be the most satisfactory for operation from 30 to 100° F., and that an SAE 80 would be better below 30° F.

A similar procedure can be followed with the rear axle, as shown in the same figure. In the case of the axle, the experimental points are indicated by the capital letter **A**, and the slope of the viscosity-leveling-off-temperature line is much steeper than in the case of the transmission. With the use of hypoid lubricants in the rear axle, the extreme-pressure characteristic of the lubricant is of more importance than the viscosity. However, as in the case of transmissions, if a lubricant with too high a viscosity is used, the operating temperatures are higher and the mechanical losses greater.

In the case of motor oils, if it is felt desirable to keep the crankcase viscosity above 40 sec and 55 sec (Saybolt), the desired viscosity-temperature parallelogram is shown in Figures 3 and 4. Figure 3 shows the location of the parallelogram on the full chart, and Figure 4 is for a small area of the large chart in order to make the relations clearer. The experimental points for "levelling-off" temperatures were obtained under the same conditions as for the transmission and rear axle, 60 miles per hour at road load, and an air temperature of 60° F. The experimental points are indicated in Figure 4 by circled crosses. An examination of Figure 4 will show that, with 100° F. air temperature, SAE 30 oils would be satisfactory, and practically all SAE 20 oils, about one-half 20-W oils, and SAE 10 oils would be satisfactory. At 60° F., all 20-W, SAE 20, and SAE 10 oils would be satisfactory. At 30° F., 10-W and SAE 10 would be satisfactory; and below 0° F., 10-W would be the only satisfactory oil. The result of this type of analysis would lead to the recommendation of SAE 30 for

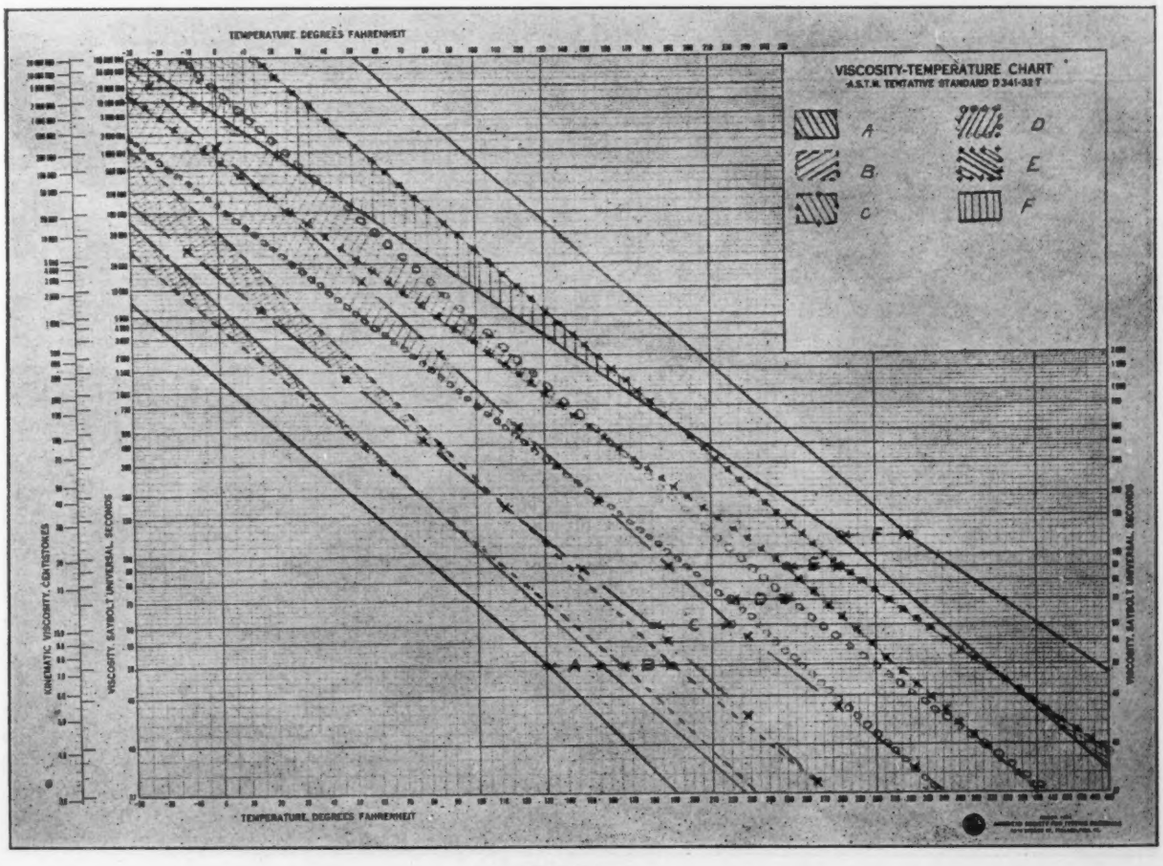

FIGURE 5

hot-summer weather, SAE 20 for average-summer, SAE 10 for ordinary-winter, and 10-W for extreme-winter. Because of the overlapping of the classification ranges, this recommendation is not fair to some oils which could be used satisfactorily in normal winter, average summer, *and* hot summer. These oils, under the present classification, might be called 10-W, 20-W, SAE 10, or SAE 20. There is no way in the present classification by which these oils could be identified as almost universal all-year-round oils which, for the case described, they really may be. This condition is confusing to the consumer if an attempt is made to explain it to him, and is unfair and costly to the oil refiner because he must carry more grades of oil than necessary.

The foregoing discussion raises the question: Is it impractical to work out a viscosity classification in which there is much less overlapping of ranges at the more commonly-used temperatures? To illustrate what is meant by less overlapping, the classification shown in Figure 5 is presented. At this point the author wishes to make it very clear that he is not of the opinion that the details of this *particular* classification have been worked out fully. The ranges may be too wide, the working range of temperature may not be covered properly, some groups may be too wide, others too narrow; *but* such a classification has almost no overlapping in the working temperature ranges, is obviously more understandable and, therefore, more usable and more valuable to all concerned. In this particular classification the limits are temperature limits at a given viscosity instead of viscosity limits at a given temperature. The several classifications are marked **A, B,** and **C.** These letters are only a means to identify the several ranges in this particular discussion. The examples of transmission, rear-axle, and engine temperatures and viscosities used previously with the present classification are repeated on the non-overlapping classification in Figure 6. The probable recommendations using this classification would be:

	Transmission	Axle	Engine
Summer (overlapping into spring and fall)	D	D	C
Winter (overlapping into spring and fall)	C	C	B
Extreme winter	B	B	A

It should be kept in mind that the values for change in "leveling-off" temperature given, although actually obtained experimentally, do not by any means represent all cars. The actual values for most cars are unknown. The assumption that the lubricant temperature falls one degree when the air temperature falls one degree is a pure assumption. Conclusive experimental data are lacking. Some data indicate that the actual lubricant temperature changes but little with change in air temperature; in some cases it actually has risen. It may well be that data of this kind have not been obtained because of the confused concept of the actual viscosities *at the working temperatures* for the various oils as now classified. The literature is full of references to tests made with 10-W, 20-W, SAE 20, SAE 30, etc., motor oils, and conclusions drawn without any clear indication that under the conditions of test some of these oils might or might not have had the same actual viscosity.

In conclusion, the author wishes to repeat the question previously asked: Is it necessary that the classification of motor oils and other lubricants have overlapping ranges within the usually-encountered operating temperatures?

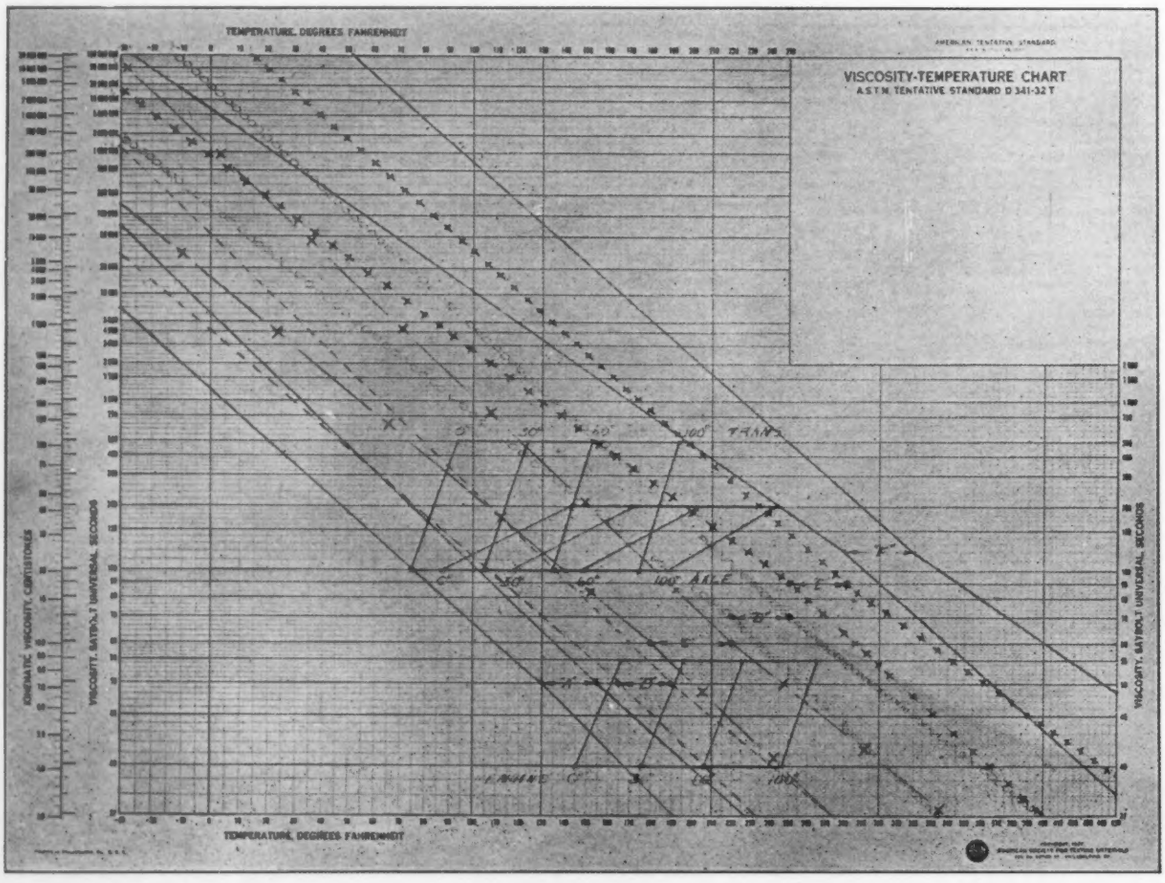

FIGURE 6

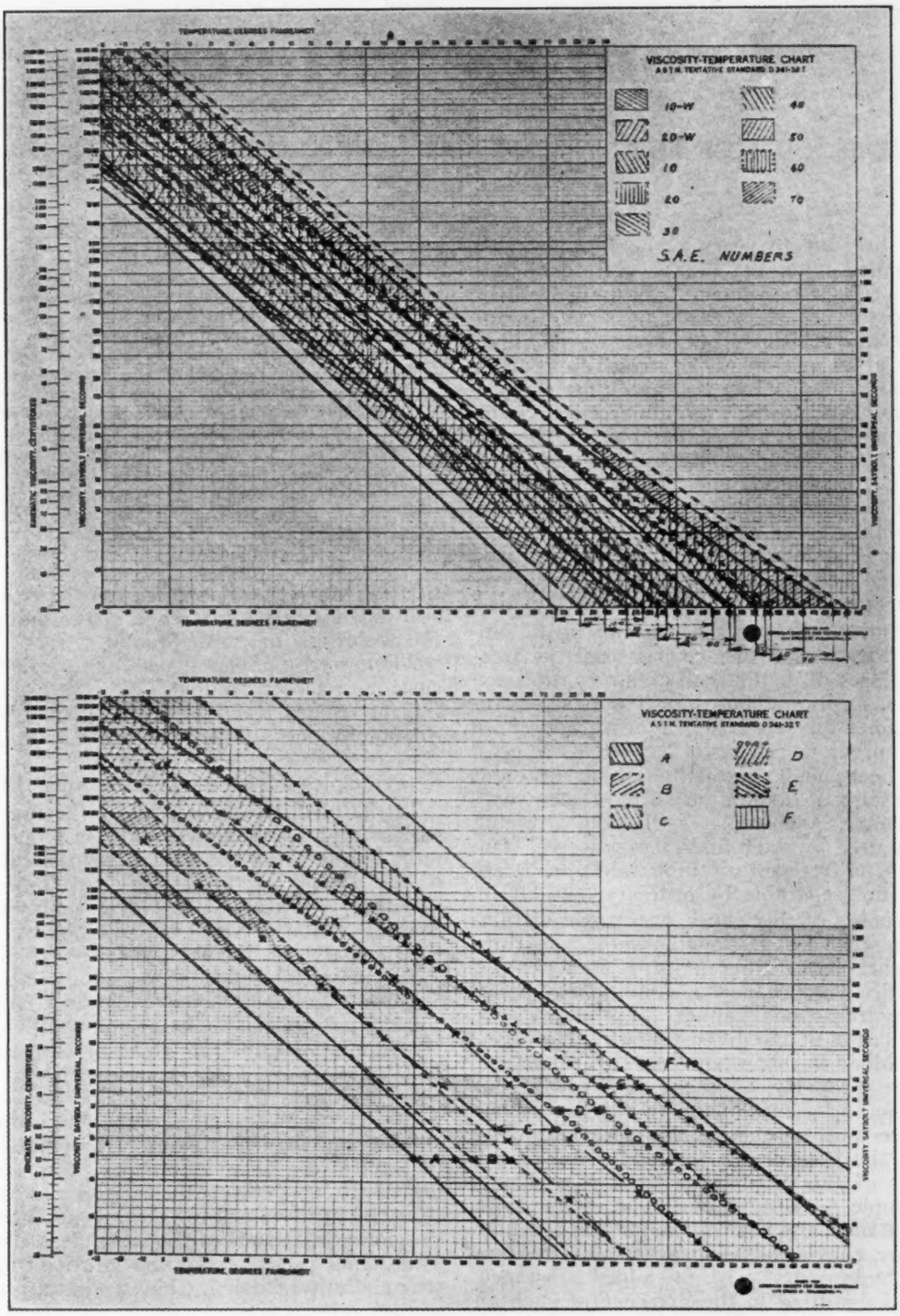
VISCOSITY-TEMPERATURE CHART
10-W
20-W
10
20
30
40
50
60
70
S.A.E. NUMBERS
VISCOSITY-TEMPERATURE CHART
A
B
C
D
E
F

FIGURE 7

Use of Azeotropic Distillation In Separating Hydrocarbons From Petroleum

FREDERICK D. ROSSINI*, BEVERIDGE J. MAIR,† and AUGUSTUS R. GLASGOW, JR.‡

THERE is presented a brief discussion of azeotropic distillation, including the principles involved, the substances that form azeotropic mixtures with hydrocarbons, the separation of hydrocarbons by azeotropic distillation, the benefits of prior distillation at reduced pressure, the separations obtainable, and mention of some commercial applications.

This paper was presented to Division of Refining, before the Twenty-first Annual Meeting of the American Petroleum Institute, Chicago, November 13, 1940.

WITHIN the past 10 years a chemical industry has been founded upon the use of petroleum as a raw material. The development of this petroleum chemical industry has been made possible through the separation in a relatively pure state of individual hydrocarbons from petroleum or from appropriate products of the refining process. There now are produced by such separations, in commercial or semi-commercial quantities, a considerable number of pure hydrocarbons, including methane, ethane, propane, *iso*butane, normal butane, *iso*pentane, normal pentane, neohexane, ethylene, and propylene, together with mixtures of isomers of the same class of hydrocarbons, such as the mixed hexanes, mixed heptanes, mixed octanes, mixed butenes, and aromatic concentrates of benzene, toluene, and "xylene."

In the separation of pure hydrocarbons in the laboratory, API Research Project 6 has used the fractionating processes of distillation, crystallization, extraction, and adsorption. These same tools are available to the refiner for separating hydrocarbons on a large scale. In previous reports of Research Project 6 mention has been made of distillation at different pressures, and also of distillation with an azeotrope-forming substance. Azeotropic distillation, although not commonly used by the refiner, is a powerful fractionating tool, and frequently can be used to separate hydrocarbons not separable by ordinary distillation.

For the purposes of this paper, azeotropic distillation may be described as follows: Assume a mixture of two hydrocarbons of different type, as a paraffin and an aromatic, which have the same boiling point. These two hydrocarbons cannot be separated by ordinary distillation at the given pressure. However, there may be added to this mixture a third substance, which has the property of changing by different amounts the boiling points of the two hydrocarbons in the mixture and so making them separable by distillation in the presence of this added substance. The first part of the distillate will be a constant-boiling azeotropic mixture of one hydrocarbon with the added substance, and the last part of the distillate will be another constant-boiling azeotropic mixture of the second hydrocarbon with the added substance. The process of distilling in the presence of such an added azeotropic-forming substance constitutes azeotropic distillation. The added substance subsequently is removed from the azeotropic distillate in an appropriate manner. The sharpness obtainable in the separation of two hydrocarbons by such azeotropic distillation depends in general upon the efficiency of the still and upon the difference in the boiling points of the azeotropic mixtures produced.

The purpose of this paper is to present a brief discussion of azeotropic distillation, and to indicate how this little-used fractionating tool may be applicable to some of the problems of the refiner.

Principles Involved in Azeotropic Distillation

In the ideal liquid solution the partial vapor pressure of each component is directly proportional to its mole fraction, and the total vapor pressure is the sum of the partial vapor pressures of the several components. The laws of the ideal solution imply that the interaction between unlike molecules is the same as that between like molecules.

In many real solutions it is found that the ideal-solution laws are obeyed. One such example is the solution of normal heptane and methylcyclohexane, the vapor pressures for which are illustrated in part **I** of Figure 1.

Deviations from the laws of the ideal solution will occur when the interaction between unlike molecule is significantly different from that between like molecules. Such deviations may be manifested by partial vapor pressures either greater than or less than the ideal values for the given concentrations of components. Part **II** of Figure 1 gives the partial and total vapor pressures for the solution of normal heptane and ethyl alcohol, which yields a mixture having a total vapor pressure greater than that of the more volatile pure component, ethyl alcohol, and there results a minimum-boiling azeotropic mixture. Part **III** of Figure 1 gives similar data for the solution of acetone and chloroform, which yields a mixture having a total vapor pressure less than that of the less-volatile pure component, chloroform, and there results a maximum-boiling azeotropic mixture.

One characteristic feature of the temperature-

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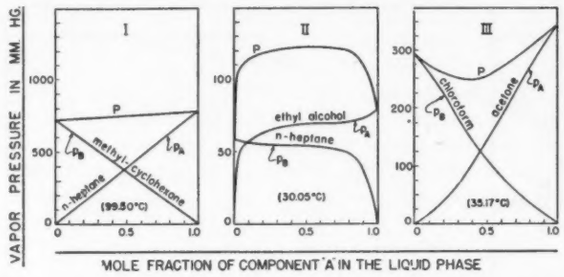
composition diagrams for those systems forming azeotropic mixtures is that, except at the composition of the constant-boiling mixture, the difference in composition between the liquid and vapor phases is usually much greater than it is in systems that do not form azeotropic mixtures. This difference in the shapes of the liquid-vapor curves for the two kinds of solutions is illustrated in Figure 2, which gives the temperature-composition diagrams for the system of benzene and *n*hexane and for the system of benzene and ethyl alcohol. The much greater difference in composition (except for the constant-boiling mixture) between the liquid and vapor phases for the latter system than for the former is readily apparent. The separation of the azeotropic mixture of benzene and ethyl alcohol from either pure benzene or pure



The scale of ordinates gives the vapor pressure in millimeters of mercury, and the scale of abscissae gives the mole fraction of the component that is the more volatile in the pure state. The data are from the following sources: 1, from Beatty and Calingaert,[2] and Willingham and Rossini[3]; 2, from Ferguson, Freed, and Morris[4]; 3, from Zawidsky.[1]

FIGURE 1
Partial and Total Vapor Pressures for the Ideal and for Eight Real Binary Solutions.

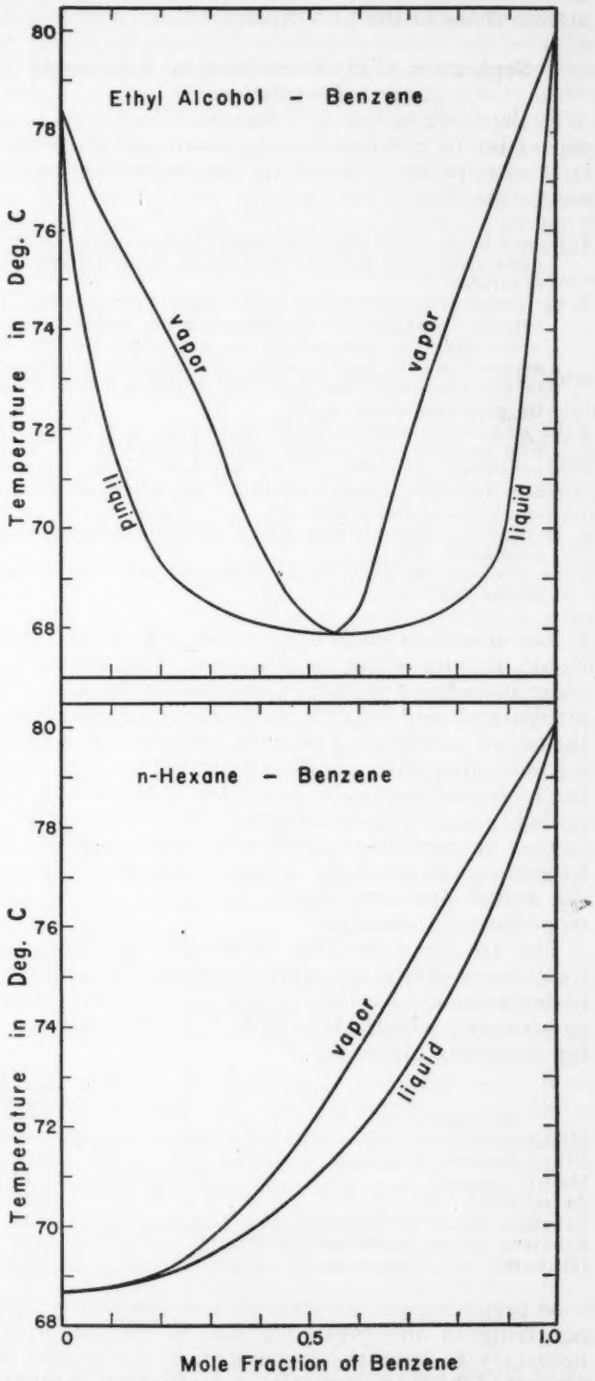
ethyl alcohol may be accomplished with distillation apparatus of relatively small separating efficiency.

Azeotropic Mixtures with Hydrocarbons

With some exceptions, nearly all polar organic molecules of the proper voltality form with hydrocarbons of the paraffin, naphthene, aromatic, and olefinic classes mixtures that have a total vapor pressure greater than that of the more-volatile pure component, yielding minimum-boiling azeotropic mixtures. The organic compounds that form azeotropic mixtures with these hydrocarbons include those containing hydroxyl, carboxyl, cyanide, amino, nitro, and other structural groups that tend to produce polarity in organic molecules. For a substantially complete list of the data that have been published on azeotropic mixtures having a hydrocarbon as one component, the reader is referred to the publications of Lecat.[8, 9, 10, 11]

For the five binary minimum-boiling azeotropic mixtures formed between a given azeotropic-forming substance and a paraffin, naphthene, monoolefin, diolefin, and aromatic hydrocarbon, respectively, with the five hydrocarbons having about the same boiling point, the lowering of the boiling point will be greatest for the paraffin azeotrope and least for the aromatic azeotrope, with the others intermediate and generally in the order given.

For the binary azeotropic mixtures formed between a given azeotrope-forming substance and the members of a homologous series of hydrocarbons, both the boiling point and the composition of the azeotropic mixtures approach, with increase in the boiling point of the hydrocarbon, those of the pure azeotrope-forming substance; i.e., for example, the azeotropic mixture of ethyl alcohol and normal pentane will have a boiling point just below that of the pure hydrocarbon, and the composition will be low in alcohol and high in hydrocarbon; whereas the azeotropic mixture of ethyl alcohol and normal octane will have a boiling



The scale of ordinates gives the temperature in degrees C, and the scale of abscissae gives the mole fraction of benzene. The diagram for the system of ethyl alcohol and benzene is constructed from the data of Fritzweiler and Dietrich,[6] whereas that for the system of *n*hexane and benzene is constructed from the data of Tongberg and Johnston.[5]

FIGURE 2
Diagrams of Temperature Vs. Composition for Both the Liquid and Vapor Phases for the Binary Solutions of Ethyl Alcohol and Benzene and of *n*Hexane and Benzene, at a Pressure of 1 Atmosphere.

point just below that of pure ethyl alcohol, and the composition will be low in hydrocarbon and high in alcohol. Conversely, for the binary azeotropic mixtures formed between a given hydrocarbon and the members of a homologous series of azetrope-forming substances, both the boiling point and composition of the azeotropic mixtures approach, with increase in the boiling point of the azeotrope-forming substance, those of the pure hydrocarbon.

Separation of Hydrocarbons by Azeotropic Distillation

In the work of the API Research Project 6 on the separation of hydrocarbons by azeotropic distillation, it is usually required of an azeotrope-forming substance that it:

1. have a boilig point near (not more than about 30 or 40° C. away from) the boiling range of the hydrocarbons to be separated;
2. be completely soluble in water and preferentially less soluble in the hydrocarbon at room temperature, in order that the removal of the azeotrope-forming substance from the hydrocarbon with which it is associated in the azeotropic distillate may be accomplished easily by extraction with water;
3. be completely soluble in the hydrocarbon at the distillation temperature, and for some degrees below this, in order that two phases shall not form in the condenser and reflux regulator and thus cause difficulty in the operation of the latter;
4. be readily obtainable in a sufficiently pure state at reasonable cost; and
5. be non-reactive with hydrocarbons or with the material of the still.

For operation on a large scale, the above criteria would require some modification. For example, in order to reduce the cost of processing, the azeotropic distillate should be rich in hydrocarbon and lean in the added substance. This calls for an azeotrope-forming substance with a boiling point higher than that of the hydrocarbons to be separated. This modification probably would be accompanied by a decrease in the degree of separation obtainable with a given still. Likewise, operation on a large scale would require the actual recovery and recirculation of the azeotrope-forming material.

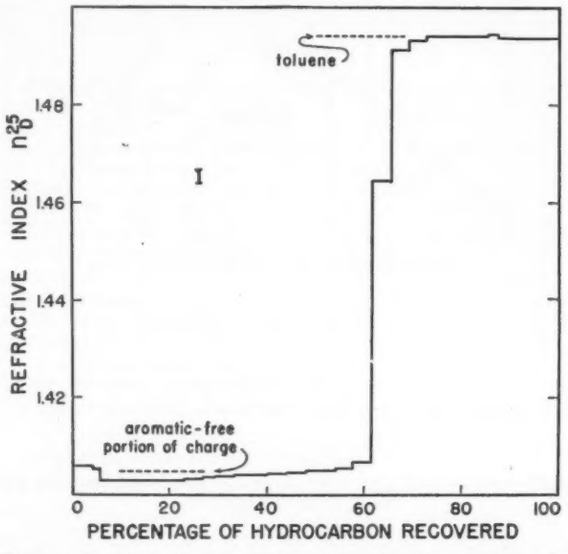
The azeotrope-forming substances that have been used successfully in this laboratory in separating hydrocarbons according to type include the following compounds, which alone boil approximately at the temperatures given:

Compound	Boiling Point at 1 Atmosphere (Deg C)
Methyl alcohol	66
Ethyl alcohol	78
Methyl cyanide	82
Acetic acid	118
Ethylene glycol monomethyl ether acetate	143
Ethylene glycol monobutyl ether	171
Diethylene glycol monomethyl ether	193

In preparing for the separation of the hydrocarbons occurring in any given fraction of petroleum, it is necessary to have the mixture of hydrocarbons well separated by a systematic and efficient distillation into a series of substantially constant-boiling fractions, prior to the azeotropic distillation. This is necessary in order to avoid having any paraffins mixed with lower-boiling naphthenes and, in turn, any paraffins and naphthenes mixed with lower-boiling aromatics, which kind of mixing will tend to nullify the separation normally attainable by the azeotropic distillation of mixtures of hydrocarbons of the same boiling point.

Benefits of Distillation at Reduced Pressure

By the same reasoning, any preliminary fractionation that will serve to displace paraffin hydrocarbons into mixtures with higher-boiling naphthenes, and, likewise, paraffin and naphthene hydrocarbons into mixtures with higher-boiling aromatic hydrocarbons, will enhance the separation over that attainable in the azeotropic distillation of hydrocarbons of the same boiling point. One process that will displace the various hydrocarbons in exactly the manner required for this enhancement of the separation is that of distillation at a pressure reduced below that of the normal distillation pressure. Distillation at reduced pressure serves to displace paraffin hydrocarbons into fractions with normally higher-boiling naphthenes. Likewise, distillation at reduced pressure displaces



The scale of ordinates gives the refractive index of the hydrocarbon recovered from the azeotropic distillate, and the scale of abscissae gives the percentage of the hydrocarbon recovered. The distillation was performed in a Bruun[1] glass bubble-cap column, of 138 rectifying units, equipped with a special pot, head, and jacket assembly,[2] with a reflux ratio of about 40 or 50 to 1, a rate of removal of distillate of about 20 to 25 ml per hour, and a total time of distillation of about 100 hours.

The plot shows the results of the azeotropic distillation, with methyl cyanide at atmospheric pressure, of a mixture of toluene (boiling point 110.6° C.) with a narrow-boiling (110.0 to 110.5° C.) mixture of paraffins and naphthenes. The azeotropic distillate was by volume about 20 percent of hydrocarbon for the aromatic and about 25 percent for the paraffins and naphthenes, with the latter forming a two-phase mixture with methyl cyanide at the distillation temperature.

FIGURE 3

Diagram Illustrating the Separation of an Aromatic Hydrocarbon (Toluene) from Naphthenes and Paraffins by Azeotropic Distillation.

paraffin and naphthene hydrocarbons into fractions with normally higher-boiling aromatic hydrocarbons. This displacement is a result of the fact that the boiling points of the aromatic hydrocarbons decrease more rapidly with decreasing pressure than do those of the naphthenes and, likewise, those of the naphthenes decreases more rapidly with decreasing pressure than do those of the paraffins.

For example, as the pressure is reduced from 1 to 0.075 atmosphere for hydrocarbons of the gasoline and kerosine ranges, the boiling point of a given paraffin hydrocarbon may be lowered about 85° C.; whereas for a naphthene and an aromatic hydrocarbon of about the same boiling point at 1 atmosphere

the lowering will be greater—about 2° C. more for the naphthene and about 5° C. more for the aromatic.

Separations Obtainable

The results obtained in separating aromatic hydrocarbons from naphthenes and paraffins by azeotropic distillation are illustrated in Figure 3, the separation being indicated by the change in refractive index with the amount of hydrocarbon recovered. Figure 3 shows the separation obtained in the azeotropic distillation, with methyl cyanide (boiling point 82° C.), of a mixture of toluene (boiling point 110.6° C.) with a substantially constant-boiling (110.0 to 110.5° C.) fraction of petroleum containing paraffin hydrocarbons with some naphthenes. The separation of toluene from these paraffin and naphthene hydrocarbons having substantially the same boiling point is almost quantitative. The separation of toluene from the appropriate fraction of petroleum would be accomplished with even greater ease for the reason that, in ordinary distillation with a mixture of paraffin and naphthene hydrocarbons, toluene tends to be displaced into fractions containing lower-boiling paraffins and naphthenes, because the toluene in such a mixture possesses a partial vapor pressure in greater excess of the ideal value called for by its concentration than do the paraffin and naphthene hydrocarbons. Such a displacement, operating in a direction similar to the displacement produced by distillation at reduced pressure, enhances the separation obtainable in the azeotropic distillation.

As contrasted with the relatively easy separation of aromatic hydrocarbons from naphthenes and paraffins, the separation of naphthenes from paraffins is accomplished with greater difficulty.

From the data that are now available, the following conclusions may be drawn with regard to the fractionation obtainable by azeotropic distillation in rectifying columns of from 50 to 100 theoretical plates:

1. Aromatic hydrocarbons may be separated from naphthenes and paraffins with relative ease by one appropriate azeotropic distillation, in mixtures in which the aromatic hydrocarbons are ones that normally have boiling points not significantly less than the boiling points of the naphthenes and paraffins in the given mixtures.

2. Naphthene hydrocarbons may be separated from paraffins by several distillations with an appropriate azeotrope-forming substance, in mixtures in which the naphthene hydrocarbons are ones that normally have boiling points not significantly less than the boiling points of the paraffins in the given mixtures.

3. Aromatic hydrocarbons of different degrees of "aromaticity," as for example an alkly benzene, an alkyl tetrahydronaphthalene, and an alkly naphthalene, may be separated from one another, in mixtures in which the various aromatic hydrocarbons have substantially the same normal boiling points, or in which any differences in boiling point are of the same magnitude and sign as the differences in the boiling points of the corresponding binary azeotropic mixtures. Such separations may require one or more azeotropic distillations, depending upon the nature of the components of the mixture and its complexity.

4. Naphthene hydrocarbons having different numbers of naphthene rings may be separated from one another, in mixtures in which the various naphthene hydrocarbons have substantially the same normal boiling points, or in which the naphthenes with two rings are ones that have boiling points not significantly less than the boiling points of the naphthenes with one ring. Several azeotropic distillations usually will be required for the substantially complete separation of such compounds.

The actual production on a large scale of individual hydrocarbons, or groups of isomeric hydrocarbons, from petroleum or any of its products, by utilizing distillation in its several variations, will involve the following preliminary steps: 1, the determination of what compounds or groups of compounds are wanted; 2, the selection of a suitable source material for the given hydrocarbons, as a given crude petroleum or petroleums, or one or more of the products of the conventional refining process, or one or more of the products of the newer processes being utilized in the refining of petroleum to obtain special products; 3, the selection of the appropriate azeotrope-forming substances to be used, consideration being given to the composition of the azeotropic-mixtures that will be produced, the initial cost of the azeotrope-forming substances, and the ease and completeness of its recovery from the azeotropic distillate.

Commercial Applications of Azeotropic Distillation

A number of commercial applications of azeotropic distillation already have been made. One example is the use of the benzene to obtain absolute ethyl alcohol from its minimum-boiling azeotropic mixture with water, which has the composition 95.6 percent by weight of ethyl alcohol and 4.4 percent by weight of water, and has a boiling point about 0.2° C. below that of pure ethyl alcohol.[12] In this case, benzene is used to break up an already existing binary azeotropic mixture through the formation of a ternary azeotropic mixture. When the quantity of benzene is in excess of that required to remove all the water as a component of the ternary azeotropic mixture, the products of distillation are, in order: 1, a ternary azeotropic mixture of benzene, ethyl alcohol, and water; 2, a binary azeotropic mixture of benzene and ethyl alcohol; and, 3, ethyl alcohol alone. Another process for obtaining absolute ethyl alcohol by azeotropic distillation utilizes trichloroethylene as the azeotrope-forming substance.[13] In this latter case similar minimum-boiling ternary and binary azeotropes are formed.

Another application of azeotropic distillation is in the purification of commercial dioxane by removing the impurities of low-boiling aldehydes through the addition of water and a volatile inorganic acid, such as hydrochloric, hydrobromic, or sulfurous.[14] In this case it is reported that the low-boiling aldehydes are removed as a component of a minimum-boiling quarternary azeotropic mixture consisting of the aldehydes, water, the inorganic acid, and dioxane.

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[*Continued from page 110*]

in Table 2, and the test data are shown in Table 3 and in Figure 12.

Run 1A is a normal run. It is apparent that, when most of the oil that gets past the pistons is burned and discharged through the exhaust—largely as CO_2, CO, and H_2O—most of the changes in the crankcase oil take place in the crankcase. However, as shown by run 2A, it is possible to have operating conditions

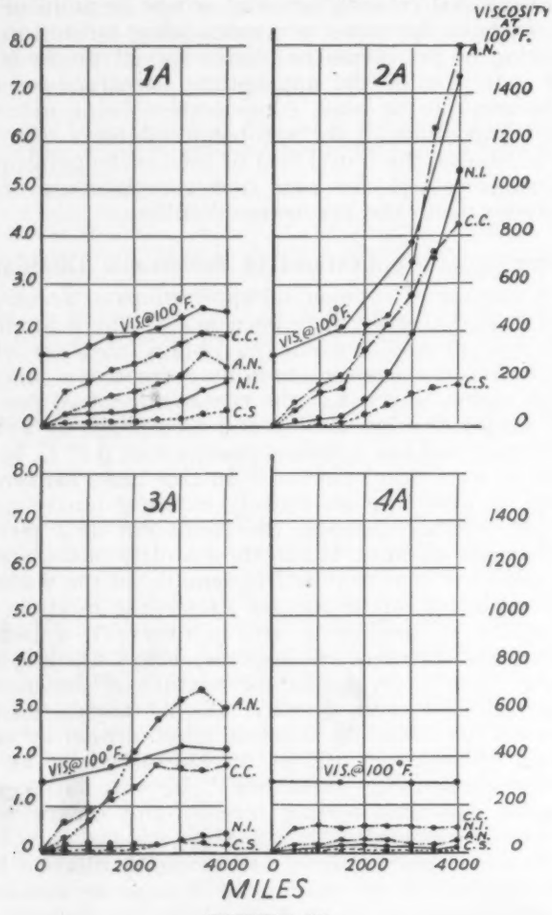

FIGURE 12
Used-Oil Analyses, Oils 1A to 4A, Inclusive.

(Data from General Motors Research General Chemistry Department.) *A.N.*, acid number; *C.C.*, Conradson carbon; *N.I.*, naphtha-insoluble; *C.S.*, chloroform-soluble.

under which an appreciable portion of the oil that gets on the cylinder walls is only partly oxidized, and some of it can get back into the crankcase—further contaminating the crankcase oil. Run 3A illustrates operating conditions wherein practically all the change in the oil occurs as a result of oxidation in the crankcase, and run 4A shows how this oxidation of oil in the crankcase may be prevented by the use of an inhibitor.

Tests Nos. 5 and 5A show the very great improvement that resulted from adding a suitable oxidation inhibitor to oil "A." Photographs of the pistons from these two runs are shown in Figure 13. Tests Nos. 6 and 6A show the advantage of having a base stock from which the easily-oxidizable sludge-forming materials have been removed. However, as previously noted, if such a highly refined oil should not contain sufficient oxidation inhibitor, it is subject to oxidation at elevated temperature with formation of corrosive acids, and with the formation of oil-soluble oxidation products which may be precipitated by the addition of fresh oil—forming sludge, varnish, and eventually coffee grounds.

Tests Nos. 7 to 7C, inclusive, show that, although a detergent may help very greatly in preventing the oxidation and decomposition products from sticking to the engine parts, the problem is only partly solved

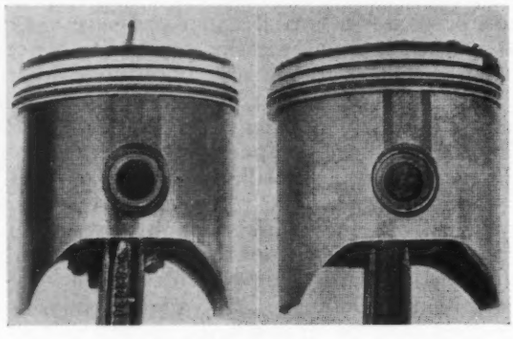

FIGURE 13
Pistons from Runs on Oils 5 and 5A.

The dark-colored piston is from the run on October 5. The dark color is the varnish formed on the piston in this run. The light-colored piston is from the run on oil 5A. Note the absence of deposits.

by the use of a detergent, unless the oil is also resistant to oxidation. These tests also illustrate the difficulty in predicting the condition of the engine from used-oil analysis above. Other conclusions to be drawn from this series of tests are that, if a choice must be made between two oils—one with good inhibitor but poor detergent values, and one with poor inhibitor and good detergent values—it is apparent that for the operating conditions of this test the oil with the better oxidation resistance would be preferable. However, the more desirable combination is an oil good in both oxidation resistance and in detergency.

Tests Nos. 8 and 8A show the importance of crankcase-oil temperatures, and illustrate the point

TABLE 3
Operating Conditions

Run No.	Decomposition Products from Combustion Chamber	Oil Analysis	Engine Condition (Disregarding Possible Effect of the Oil on Alloy Bearings)
1A	Normal, normal testing operating condition	Bad	Good
2A	Large amount of decomposition products resulting from partial decomposition of oil in combustion chamber	Very bad	Very bad
3A	Very low combustion-chamber temperature, almost all of decomposition products in oil originating at crankcase oil	Bad	Good
4A	Very low combustion-chamber temperature, with formation of decomposition products in crankcase oil prevented by oxidation inhibitor	Very good	Very good

TABLE 4
Oils for Gasoline Engines

Test No.	Purpose of Test	Oil	Miles of Test	Oil Analysis at End of Test			Engine Condition at End of Test		
				Acid No.	Naphtha-insoluble (Percent)	Chloroform-soluble (Percent)	Sludge	Varnish on Pistons	Effect of Oil on Alloy Bearings
5	To show effect of oxidation inhibitor	Oil A, solvent-refined high VI 10-W.	3,500	3.44	2.28	0.73	Slight	Very bad	Corrosive
5A	.....	Oil A plus 3 percent sulfur-saponifiable oxidation inhibitor.	4,000	0.39	0.63	0.05	None	None	Non-corrosive
6	To show effect of base oil.	Highly-refined high VI 20-W.	4,000	1.26	0.92	0.29	Slight	None	Corrosive
6A	.....	Conventional-refined Mid Continent 20-W.	2,000	0.66	1.07	0.87	Very bad	Very bad	Non-corrosive
7	To show effects of detergent and oxidation inhibitor.	Oil B, highly-refined high VI 10-W.	2,000	7.70	0.99	0.45	None	Pistons stuck transparent varnish	Very corrosive
7A	.....	Oil B plus metal compound detergent	3,000	9.70	3.41	1.75	None	None	Very corrosive
7B	.....	Oil B plus 3 percent sulfur-saponifiable oxidation inhibitor.	4,000	0.46	0.48	0.11	None	None	Non-corrosive
7C	.....	Oil B plus 3 percent sulfur-saponifiable oxidation inhibitor plus metal compound detergent.	4,000	0.22	0.38	0.08	None	None	Non-corrosive
8	To show effect of crankcase-oil temperature.	Oil C "medium-quality" medium VI oil with crankcase-oil temperature held at 280 degrees F.	4,000	2.62	2.01	1.85	Very bad	Very bad	Corrosive
8A	.....	Oil C, but with crankcase-oil temperature held at 200 degrees F.	4,000	0.27	1.16	0.33	Good	Good	Non-corrosive

that, even though an oil of "medium quality" may be very satisfactory for medium service, for "heavy duty" oils of superior properties are required.

Oils for Diesel Engines

Typical results of tests made on model 71 General Motors Diesel engines, in accord with the Detroit Diesel Division test procedure, are shown in Tables 5 and 6.

The oil-analysis data from the samples of used oil, taken during the test runs, are shown in Table 6. In accord with the test procedure, the first 144 hours are run without a sludge filter. The filter is installed at 144 hours and used during the remainder of the test, changing filters when necessary. With oils "F" and "H" only one filter was used; with oil "G," seven filters were used.

In the case of oil "G," this was more than was actually necessary, because in the test with this oil the filter would remain in good condition about 125 hours; but the extra filters were used to learn more about the effect of filters, and to try to find out if more frequent changing of the filters would remove the desirable addition agents in this oil.

If an oil is low in detergent properties, the decomposition products from the oil tend to stick to all engine parts, including the filter surfaces. If the oil is high in detergent properties, these decomposition products are less likely to stick to the engine parts or to be caught in a filter. This means that, in actual service, filters will plug up much more rapidly if the oil is low in detergent properties. It also means that, in order to maintain the filtering of the oil in a satisfactory manner, the filter elements must be changed much more frequently if the oil is low in detergent value. Of course, it is possible to produce an oil so high in detergent value that a filter will have no effect on the oil. The dirt is so highly dispersed that the filter will not hold it.

The subject of heavy-duty oils is very large, and there are many other points that could be developed if time permitted. Among these is the commercial problem of crankcase-oil drain periods. It is evident that, if the operating conditions are too severe, or if the crankcase-oil drain periods are too long, or if the oil is not sufficiently resistant to oxidation to be used for long periods of time without draining, then much better results would be obtained with shorter oil-drain periods.

It should be pointed out that oils differ very greatly in their ability to furnish satisfactory lubrication under severe operating conditions, and that engine operating conditions also vary over a wide range. For moderate duty, oils of a wide variety of properties appear to be satisfactory; but for higher duty, which means operation at higher temperatures, oils which are resistant to the effects of higher temperatures are very desirable, even though oils of quite poor quality may be operated under severe operating conditions if they are drained frequently enough. Certainly no one should go crazy in regard to either extreme of long or short oil-drain periods; and, regardless of any of our personal views, this is a commercial problem that will be settled for all of us by the people who pay the bills for oils and fuels and engines and maintenance.

Summary

1. With improvements in engines, fuels, and roads, the service requirements on gasoline and Diesel engines are increasing rapidly. This means that the lubricating oils should be able to lubricate the engines under the heavy-duty service conditions that are becoming more common.

2. In order to meet these requirements, the lubri-

TABLE 5
Oils for Diesel Engines

OIL	Hours of Test	Oil Analysis	Engine Condition	
			Bearings	Pistons and Rings
Oil D (medium VI oil, low in both oxidation resistance and in detergency)	100	Bad	Good	Bad
Oil E (low VI, low in oxidation resistance but good in detergency)	116	Bad	Good	Bad
Oil F (medium VI, high in oxidation resistance, and high in detergency)	500	Good	Good	Good
Oil G (high VI, high in oxidation resistance but intermediate in detergency)	500	Good	Good	Fair
Oil H (high VI, high in oxidation resistance and high in detergency)	500	Good	Good	Good

TABLE 6
Oils for Diesel Engines

HOURS	Neutralization No.					Chloroform-soluble					"Carbon" (Naphtha-insoluble Minus Chloroform-soluble)				
	Oil D	Oil E	Oil F	Oil G	Oil H*	Oil D	Oil E	Oil F	Oil G	Oil H*	Oil D	Oil E	Oil F	Oil G	Oil H*
20	0.1	0.4	...	...	...	0.04	0.05	...	...	...	0.24	0.19	...	0.18	0.06
40	0.1	0.8	...	0.1	0.3	0.12	0.1	...	0.08	0.01	0.40	0.24	...	0.28	0.06
60	0.2	0.9	...	...	...	0.24	0.3	...	...	...	0.56	0.22	0.03	0.42	0.10
80	0.4	1.4	...	0.1	0.3	0.80	0.7	...	0.06	0.02	0.88	0.42	...	0.42	0.16
100	0.4	2.2	...	0.1	0.4	1.6	1.5	...	0.08	0.02	1.6	0.64	0.05	0.36	0.24
116	...	2.1	...	...	...	...	2.2	...	...	...	...	0.80	...	...	...
125	...	...	0.2	...	...	...	...	0.15	...	...	...	...	1.29	...	...
144	...	...	†	†	†	...	...	†	†	†	...	...	†	†	†
200	...	...	...	0.2	0.5	...	...	...	0.05	0.02	...	...	...	0.04	0.20
300	...	...	...	0.2	0.5	...	...	...	0.04	0.03	...	...	...	0.04	0.34
350	...	...	0.3	...	...	...	...	0.20	...	...	...	...	2.12	...	...
400	...	...	...	0.2	0.6	...	...	...	0.04	0.02	...	...	...	0.04	0.18
500	...	...	0.3	0.4	0.7	...	...	0.18	0.04	0.02	...	...	2.17	0.04	0.22

* Analyses of oil samples from test with oil "H" were made in the laboratory of the company making the test on oil "H." However, check analyses made on several samples indicate that the results are very similar to those obtained in our laboratory, except that the neutralization numbers are somewhat higher than we would obtain. Analyses on all other oils made in our laboratory.

† In accord with the test procedure, filters were installed at 144 hours.

cating oils should be resistant to oxidation or chemical decomposition in the crankcase; the oil must not be corrosive to engine parts; the products of thermal decomposition in the combustion chamber should not be excessive; and the oil should be of such a nature that the decomposition products that get into the oil will not adhere too strongly to pistons, rings, or other engine parts.

3. Oils and fuels are just as much parts of the engine as pistons and crankshafts. Progress in engines and progress in oils and fuels must go hand in hand, and neither the oil nor automotive industry can make much progress by itself, or if progress lags behind in the other industry.

4. These desirable results can be obtained by the oil and automotive industries at the present time.

Fuel Quality Requirements

[*Continued from page 103*]

after grinding valves, with results as shown in Table 3.

Discussion

Only one of the five items of maintenance investigated showed consistent results in the direction of lower octane requirements. This item was the removal of combustion-chamber deposits, and the effect ranged anywhere from 1.6 to 15.5 octane numbers. The data show no definite relationship between octane-requirement decrease and miles driven since last carbon removal. Doubtless this variation is caused to a great extent by such factors as the type service to which the car is subjected, the amount of oil entering the combustion chamber through faulty rings, etc. However, it would appear from these tests that possibly about 15 or 16 octane-number decrease is the maximum that might be expected, whereas a decrease of 8 to 10 octane numbers in the requirement more nearly might represent an average case. It is also apparent that a 13- to 15-octane-number increase may occur in as few as 15,000 miles.

TABLE 3
Effect of Valve Grinding on Compression Pressures

CAR	Model (Year)		Compression Pressure (Pounds Per Square Inch) Cylinder Number 1	2	3	4	5	6
B-2	1939	Before	127	131	135	130	135	132
		After	128	133	134	135	136	138
B-5	1938		126	125	127	124	125	123
C-1	1939	Before	90	102	97	106	106	95
		After	97	97	97	95	105	100
C-2	1939	Before	105	105	100	105	95	100
		After	105	105	110	110	105	108
C-4	1938	Before	102	96	65	86	98	90
		After	103	105	98	110	104	98
C-6	1938	Before	120	120	108	115	107	126
		After	115	115	102	110	110	113

The only thing which can be said of the remaining four items of maintenance investigated is that they have definite effects on octane requirements, although the effect is not always in the same direction. The final average difference between the octane requirements of all the cars—as received, and after adjustments and corrective measures had been applied—was 8.7 octane numbers. Excepting the cars on which only the effect of carbon removal was studied, a decrease in requirement from an initial average of 75.5 octane number to a final average of 66.0 octane number, or 9.5 units, was secured.

In view of this great difference in octane requirements, which appears to be largely a matter of combustion-chamber deposits, one naturally wonders about the factors which might contribute to a rapid building up of deposits. Excessive choking due to badly adjusted or inoperative automatic chokes, and the condition of rings and pistons, undoubtedly play an important part in the rapid building up of combustion-chamber deposits, and as a consequence deserve some consideration on the customer's part.

These limited observations would appear to be convincing proof that maintenance items can play an important part in determining the qualities needed in gasoline for trouble-free operation. It is believed that car owners well could afford to consider more seriously the matter of periodic checkups, instead of postponing servicing until the "old bus" refuses to run.

Trends in Automobile Design Match Evolution in Fuels

T. A. BOYD and W. G. LOVELL
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THE trends toward greater comfort and better appearance, lower cost, higher power, and more miles per gallon, which have been sustained for many years in the automobile industry, largely have paralleled the evolution in fuels. In particular, the upward trend in octane number has helped in putting more performance and economy into cars year by year. Thanks to more volatile gasolines, also, automobile engines have been made to breathe more freely and to breathe cooler air. Mixture ratios, too, have been made leaner. The advances achieved year by year in fuels and in cars thus have been made to supplement one another in such a way as to yield better products, and at distinctly lower costs. Looking to the future it seems reasonable to expect that this mutual evolution will be continued as further advances permit.

This paper was presented to Division of Refining, before Twenty-first Annual Meeting of the American Petroleum Institute, Chicago, November 15, 1940.

THERE are four trends in automobile design which have been sustained for many years—trends toward:

Greater comfort and better appearance;
Lower cost, both in purchase price and in operating expense;
Higher power; and
More miles per gallon.

These four trends, and in particular the last two, are influenced by changes in the gasolines currently sold in filling stations. In respect to this influence, it should be mentioned that it is gasoline, not the car, that sets the pace. That is to say, the car does not lead the gasoline trend, but follows it. Cars must not get ahead of the trend in gasoline, for it would be folly to build an automobile engine that could not run well on the gasolines currently sold. The car designer has to bear in mind also that, although a new model may be introduced every year, nevertheless, a car once made has an average life of eight years or more,[1] and it must run on gasolines available over that period.

If the automobile trends toward higher performance and more miles per gallon are to continue, it is necessary: first, to get more and more charge of air and fuel into a cylinder of given size; and, second, to use the charge there to better and better advantage. To crowd more charge into the cylinders, either mixture temperature must be lowered or the pressure drop in the induction system must be reduced, while keeping at the same time good distribution; or a positive pressure may be applied by means of a supercharger. This demands a volatile gasoline, of course, but one which is not so volatile as to bring on disturbances such as vapor lock. To use the charge to best advantage, mixtures must be as lean as permissible, and thermo-dynamic efficiency must be as high as possible. The latter can be accomplished only through high compression ratios—and this, of course, demands gasolines that are as knock-free as possible.

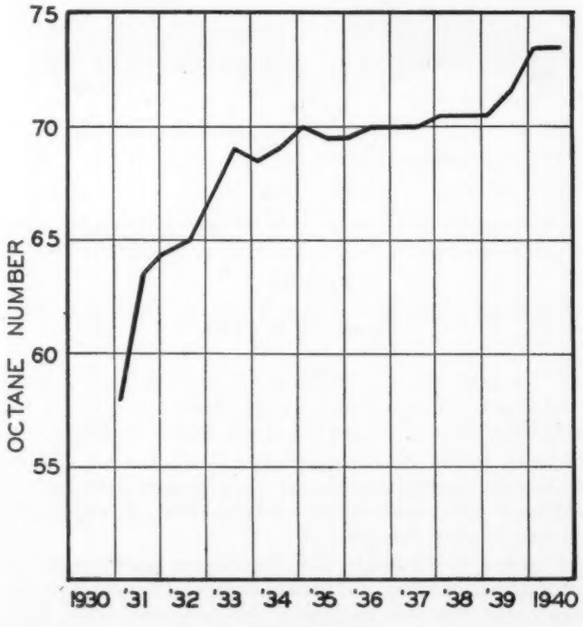

FIGURE 1
Trend of Octane Number, Regular-Price Gasoline in Detroit, Michigan.

The foregoing introduction is an outline in brief of the discussion to follow, which consists chiefly in presenting more definite information on the trends mentioned, and on how closely they have followed changes in the characteristics of the gasolines currently sold.

Changes in Gasoline

The upward trend in octane number for regular-price motor gasolines during the period 1931 to 1940 is shown in Figure 1. As may be seen, the increase has been from below 60 to about 75 (ASTM values since 1933). In Figure 2 are shown changes in volatility, as measured by distillation temperatures at representative points. On the average, the decrease in distillation temperature, or the improvement in volatility, during the 10-year period amounts to more than 25° F. at the 50-percent point, and to

from 10 to 20 degrees at other points. The values given in Figures 1 and 2 are all for regular-price motor gasolines, as sold by the 8 or 9 major distributors in Detroit, Michigan.

Comfort and Appearance

The first trend in automobile design mentioned at the outset, that toward more comfort and better appearance, is one of the most important of all, because these factors loom so large in the satisfaction of users. And the

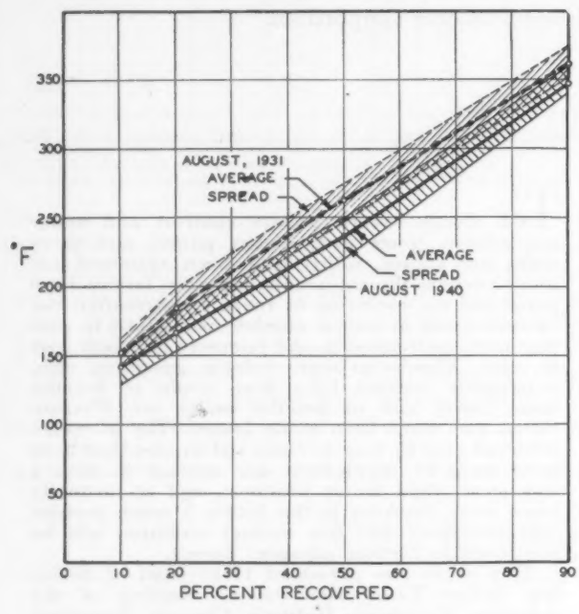

FIGURE 2
Change in Distillation Characteristics, Regular-Price Gasoline in Detroit, Michigan.

plentiful supply of gasoline at low cost, which always has been available, has exerted a major influence both upon comfort and appearance. This it has done by making it practical to build cars of large size and high performance. The higher cost of gasoline in Europe is an important one of the factors which have caused automobiles there to be smaller in size and lower in performance than those made on this side of the Atlantic.

The trend toward more volatile and more nearly knock-free gasolines also has influenced comfort and appearance, chiefly through the contributions to smooth and trouble-free engine operation. Another respect in which gasoline has influenced appearance is in such compromises in external lines as have been made to avoid trouble from vapor lock. And such compromises have been made, even though in the petroleum industry it has been thought sometimes that automobile makers have not gone far enough in this regard.

Cost

The second trend, that toward reducing the cost of owning and operating cars, has been a particularly pronounced one. The reduction in purchase price has been so large, in fact, that today the car buyer gets three times as much for his dollar as he did in 1920. As is shown in Figure 3, a representative 4-door sedan of 112-inch wheel base, which weighed 2739 pounds, retailed in 1920 for $2435. In 1939 a representative car of comparable size, one having the same wheel base of 112 inches and weighing 2845 pounds—4 percent more—retailed at less than $735. Thus the 1939 car did not cost quite a third as much as the car of equivalent size and weight in 1920.* This tremendous reduction in the cost of cars is, of course, in addition to the further benefit which the car buyer receives today in the way of a more comfortable, more beautiful, and more satisfactory automobile.

That there also has been a downward trend in cost of operation since 1926 is shown graphically in Figure 4. There it is seen that the direct cost of operating a car is only about half what it was in 1926. Cost of living, from the figures of the Bureau of Labor Statistics for 32 large cities, however, has decreased during the same period only 20 percent. The data on car-operating cost, from the Automobile Manufacturers Association, are direct operating costs for light passenger cars, based on records of 10 large fleets.[2] These data do not include such fixed or indirect operating costs as depreciation, insurance, garaging, and license fees; but they do include gasoline, oil, tires, and repairs. The decreased cost of gasoline was, of course, one important factor in the downward trend in cost of operation. And there has been a reduction in the retail cost of gasoline since 1926, in spite of the almost year-by-year mounting of taxes on gasoline. Exclusive of the tax, the reduction in the retail price of gasoline has amounted since 1926 to about 8 cents per gallon, whereas during the same period the tax on gasoline has risen from about 2.5 cents per gallon on the average to about 6 cents.[3]

Performance

The third major trend in automobile design is that towards more power. This is a trend of engineering design that also can be evaluated in definite figures. To make such an evaluation in as concrete terms as pos-

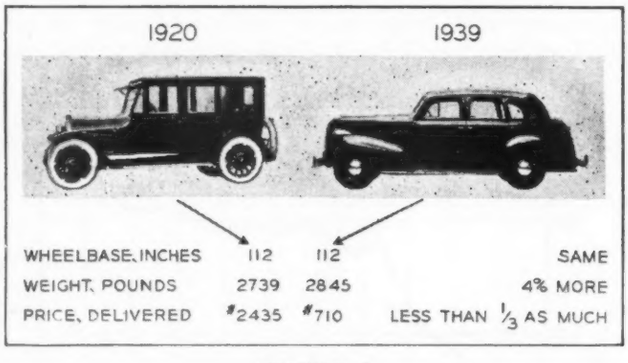

FIGURE 3
Car Buyer Now Gets Three Times as Much for his Money as in 1920.

sible, for convenience we have taken as a basis a period of 10 years and 6 makes of cars that have been in high production for this period, and have expressed the trends in terms of averages for these 6 cars. Such a selection is somewhat arbitrary, to be sure, but the data have been dealt with so as to keep them as comparable as possible over this period.

In order to evaluate the trend, we have taken the performance factor as brake mean effective pressure times cubic feet displacement per ton-mile. This factor becomes comparable between different cars because it includes an adjustment for car weight and engine displacement. It is a measure of the relative amount of

* The 1939 car is used here for comparison, because later cars in the low-price field have wheel bases longer than 112 in. and weights considerably higher. But, aside from the increase in size, the comparison made in Figure 3 would hold also for the 1941 car. The comparison given is based on a more extensive analysis made by the Automobile Manufacturers Association and published in the booklet, *Men, Methods, and Machines in Automobile Manufacturing* (1939).

power that the driver has at his command to propel the car. In other words, it is what the driver may sense as the performance of the engineering package which he has purchased under the name of an automobile. As shown in Figure 5, the trend in performance has

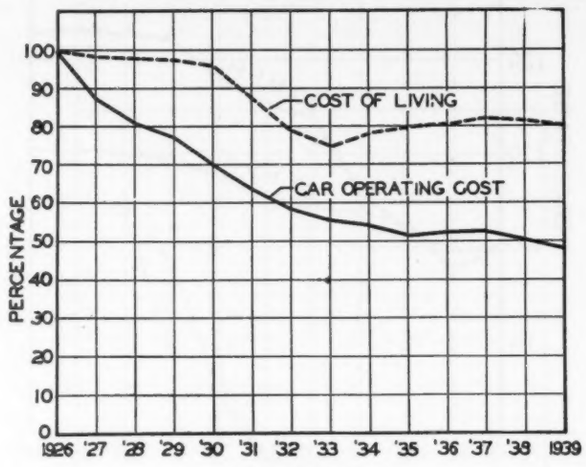

FIGURE 4
Trend of Car-Operating Cost.

been definitely upwards, and over the 10-year period an increase of about 25 percent has been achieved at 50 miles per hour and more than 10 percent at 20 miles per hour (see also, for comparison, Figure 8).

Economy

Accompanying such a very considerable increase in performance, there has been no sacrifice in fuel economy—but, on the contrary, a considerable gain. A graphical representation of this trend is shown in Figure

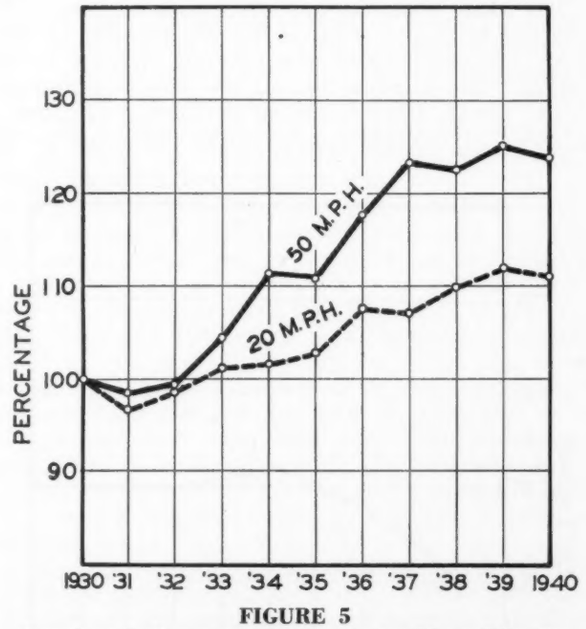

FIGURE 5
Trend of Performance Factor, Brake Mean Effective Pressure Times Cubic Feet Displacement Per Ton-Mile.

6, in which the percentage changes in the economy factor are plotted for speeds of both 50 and 20 miles per hour. This economy factor is taken as ton-miles per gallon, and over the 10-year period it shows an upward trend amounting to 25 percent at the higher speed, and to 20 percent at the lower speed.

It may be emphasized again that this gain in economy has been achieved at the same time that performance has gone up, although it is often thought that at any one time increased economy may be had only with a sacrifice of performance, or vice versa. That these two trends towards more economy and performance have been manifested simultaneously is due to the engineering advances which have been made to match a simultaneous evolution of fuels, chiefly in octane number and in volatility. In other words, through automobile engineering, better use is being made of better fuels.

Engineering Trend

The purchaser of an automobile might be said to be interested in performance and economy, without regard to the manner in which they have been achieved. But in considering these trends from the standpoint of the utilization of the fuels which to a large extent have made them possible, it is necessary to consider the design trends that are responsible for the final product. The problem of getting more performance and economy has been answered in part by putting more fuel into

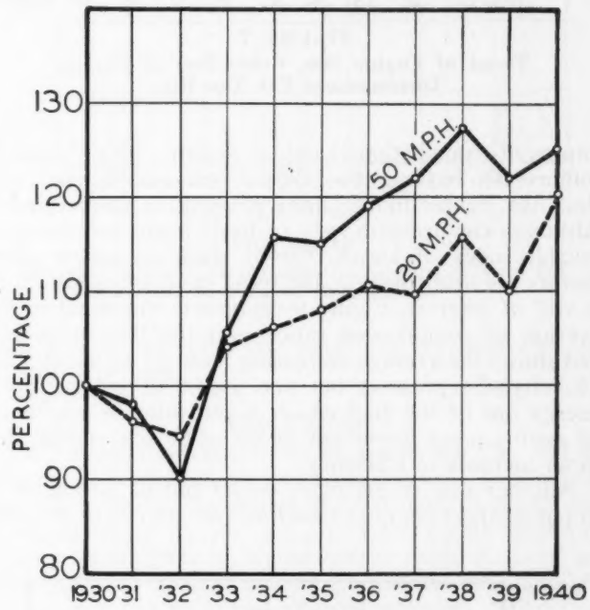

FIGURE 6
Trend of Economy Factor, Ton-Miles Per Gallon.

the same size engine, and in part by using it to better advantage.

The engine size itself has not been changed appreciably. Relative engine size, for the purpose of indicating trends, may be taken as cubic feet of engine displacement per ton-mile. As is shown graphically in Figure 7, the variation in this factor over this 10-year period has not been more than 4 percent up or down. The engines thus have not changed in relative size; therefore, as far as getting performance from cars is concerned, this must mean that more is being gotten out of them.

That there has been a trend towards getting more power out of a given size of engine is indicated by the data in Figure 8. These data, on the average brake mean effective pressures developed by this series of engines, show a fairly consistent increase, which over the 10-year period amounted to nearly 25 percent at 50 miles per hour and to 10 percent at 20 miles per hour.

This increase in available power has come from a number of sources. One source has been an increase in compression ratio, made possible by better fuels and

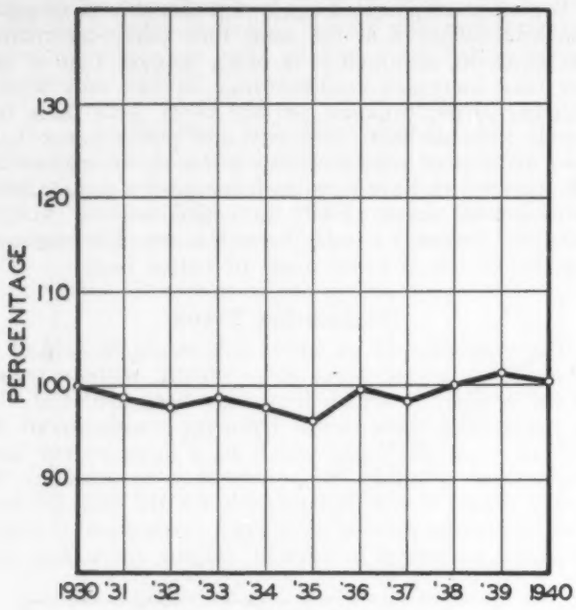

FIGURE 7
Trend of Engine Size, Cubic Feet of Engine Displacement Per Ton-Mile.

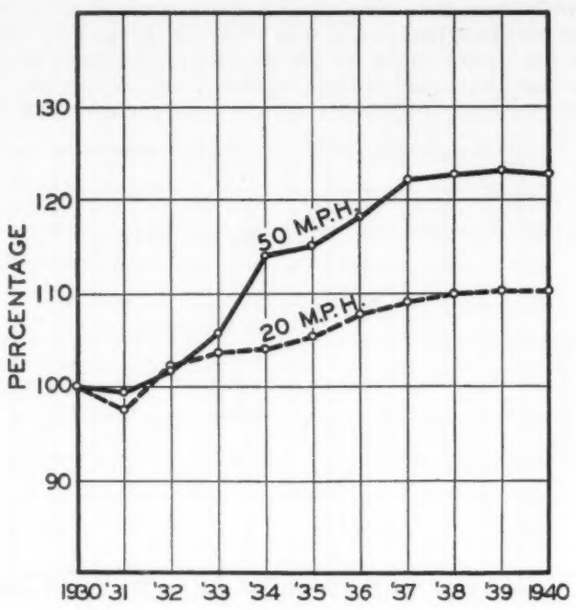

FIGURE 8
Trend of Engine Power, Brake Mean Effective Pressure at Full Throttle.

improved combustion-chamber design. This boost in compression has increased thermodynamic efficiency, and thus has yielded more power per unit of displacement. Although compression ratio of itself is not necessarily a reliable index of knock, nor of efficiency unless other factors are held constant, the trend in compression ratios is still of interest. Figure 9 represents the trend in the average of compression ratios over the 10-year period, and shows the average increasing from 4.7 to about 6.25. This trend represents but one aspect of getting more energy out of the fuel which is put into the engine or of getting more power out of the same size engine, due to an increase in efficiency.

Another way to get more power out of an engine is to put a larger charge of fuel and air into it, or to make an engine that will breathe better. Doing this offers not only the advantage of higher power, but also of better economy when other adjustments are made. The trend of engine breathing is shown graphically in the chart of relative volumetric efficiency, Figure 10. This reveals an increase of about 10 percent in volumetric efficiency at 50 miles per hour over the 10-year period. In other words, about 10 percent more fuel-air mixture goes into the engine.

This comes about not only from improvements in the induction system resulting in less restriction to the flow of air, but also from the use of cooler mixtures of fuel and air. The increase in mixture temperature above that of the air entering the carburetor may be taken as an index of mixture temperatures. The trend of this

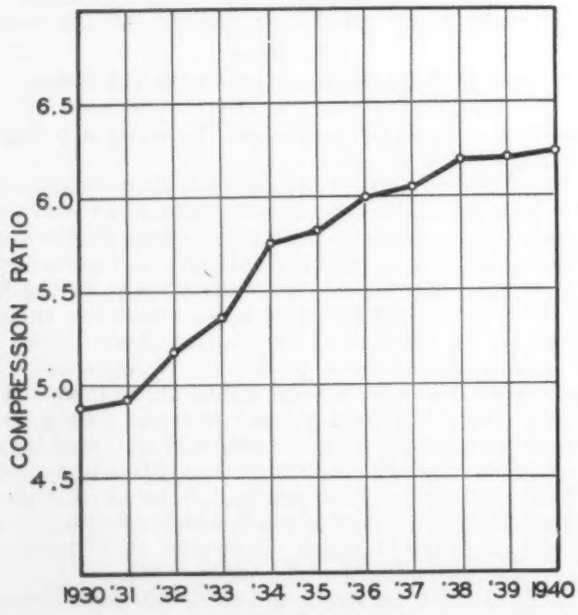

FIGURE 9
Trend of Compression Ratio.

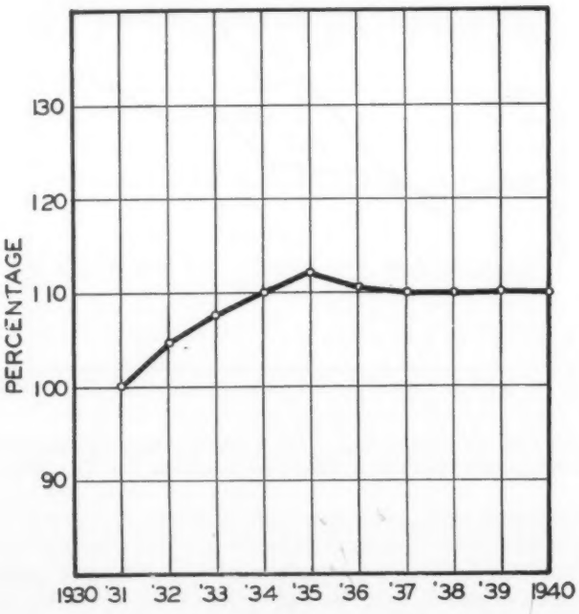

FIGURE 10
Trend of Volumetric Efficiency at 50 Miles Per Hour.

index is shown in Figure 11, which indicates a reduction of 15 to 20° F. in the mixture temperature over the 10-year period under discussion. That it is possible to use cooler mixtures and to have induction systems with less restrictions is due in part to the improvement in the volatility of gasolines; and as a result the modern engine utilizes not only its fuel, but also its own materials of construction, to better advantage.

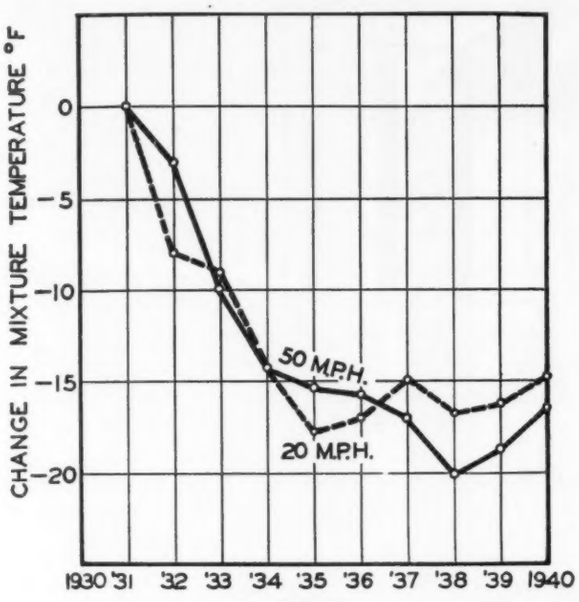

FIGURE 11
Trend of Mixture Temperature, Full Load.

Another aspect of the better utilization of fuels by engines is the trend towards the use of leaner mixture ratios in automobiles over a period of years. The advantage of the use of lean mixtures is that it results in better gasoline economy, because less fuel is wasted or sent out the tail pipe as unburned carbon monoxide and hydrogen in the exhaust gas. It also has the accompanying advantage of reducing the possible hazard from carbon monoxide in the exhaust gas.

Data on this trend are not available year by year on the six automobile makes already considered. However, data are available from a paper yet to be published, in which surveys of mixture ratios were made in comparable and representative groups of cars in the years 1927, 1933, and 1940. Such data, in terms of mixture ratio over the speed range at road load, are shown in Figure 12. Greater improvements have been made at high speeds than at low, but in general the cars of the 1940 survey were operating with mixtures about 2 ratios leaner than those of 1927. This improvement of 2 ratios, which corresponds to a saving in fuel of about 17 percent, contributes largely to the gains in miles per gallon shown in Figure 6.

This improvement in mixture ratio has been made possible primarily by advances in carburetor and induction systems, with resultant improvement in fuel distribution. And this has been possible in turn because of improvements in the volatility of gasolines. Only part of the resultant improvement has been taken directly as economy. Part of it was utilized for improving performance.

Viewed as a whole, the trends in engineering design, which have put more performance and economy into the automobile, seem to match the evolution in gasoline shown in Figures 1 and 2. Thanks in part to more volatile gasolines, automobile engines are breathing more freely, and they also are breathing cooler air. Leaner fuel-air mixtures as well are being used. Furthermore, due in part to boosts in compression made possible by more nearly knock-free gasolines, the charge once in the engine is being used more efficiently. Thus all of these changes in engineering design not only have been correlated among themselves to produce a cheaper yet better

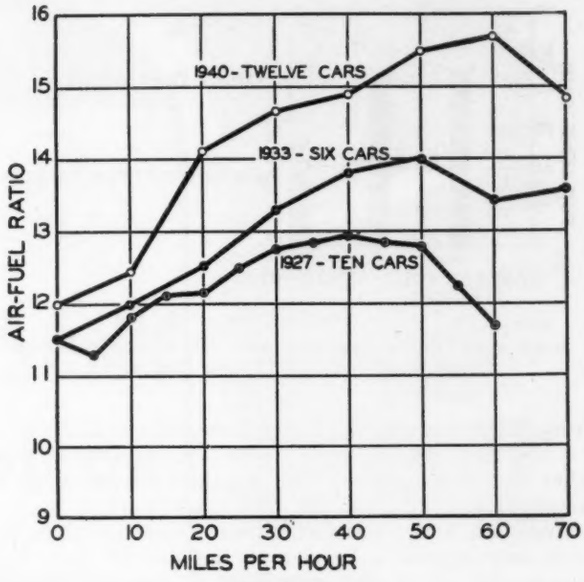

FIGURE 12
Mixture Ratios in Representative Groups of Cars for Various Years, Road Load.

final product, but they also have been matched with the evolution in fuels.

The Future

Still further advances can be made, for the end of what is possible has not yet been reached. This is true from a technical standpoint at least, and probably also from an economic one. As an indication of what can be done with fuels of higher octane number, there are presented in Figure 13 some experimental data obtained on a car in which a fuel of approximately 100 octane number was used instead of 70 octane number. When the 100-octane fuel was used, the compression ratio of the engine was increased as found possible for equivalent knock. This, of course, of itself would increase greatly the performance of the car; and in order to take the greater part of the gain of high compression as economy rather than performance, the axle ratio of the car was changed so as to maintain the original performance of the car at 20 to 30 miles per hour. The results, reduced somewhat at the low speed from the data as obtained in order to show gains due to the change in octane number alone, are presented in Figure 13. At 20 miles per hour, where the increase was altogether in miles per gallon, it amounted to more than 40 percent. At the higher speeds the gain in miles per gallon was not quite so large. These lower values were due in part to the shape of the power curve of the high-compression engine. This was such as to give a residual gain in performance above that which could be converted into an improvement in miles per gallon without major engineering changes, which in these experiments it was desired to avoid.

It may be of interest to present further, in Figure 14, similar data for the same engine with the compression

boosted to a ratio of 10.3:1, and with axle ratio further changed to give the original performance at 20 to 30 miles per hour. At this compression the fuel required was above 100 octane number; but the gains in miles per gallon were about 70 percent at 20 miles per hour, about 65 percent at 40 miles per hour, and about 50 percent at 60 miles per hour. Here, as before, there was a residual gain in performance at the higher speeds.

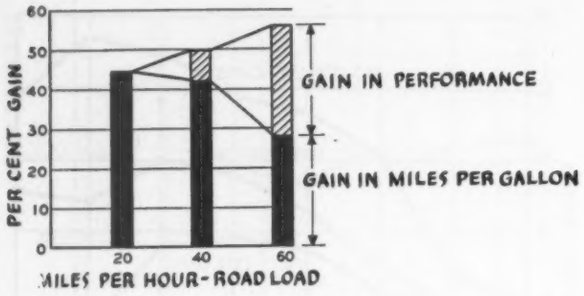

FIGURE 13
Gains with Fuel of Approximately 100 Octane Number Compared with 70 Octane Number.

From these two items of direct experimental evidence it is apparent that, in spite of the sometimes expressed belief that nothing much can be gained by going higher in octane number, quite the contrary is true.

However, under some conditions, mechanical limitations may impose a barrier to the use of very high compression ratios. But even in such engines it appears possible, through the use of supercharging, to utilize high-octane fuels to advantage, and perhaps with gains in miles per gallon almost as large as those obtained by raising compression ratio. The practicability of supercharging automobile engines has not yet been fully explored, of course. Nevertheless, an attempt, based upon such limited experimental data as are available, has been made to estimate the gains in miles per gallon which a car with a supercharged engine using 100-octane gasoline would give, compared with an unsupercharged one of the same compression ratio using 70-octane gasoline. For this purpose two assumptions were made: first, that for the same performance engine displacement could be reduced by 45 percent[4]; and, second, that the supercharger would be operative only in the case of power demands at a given speed above the output of the unsupercharged engine. At road loads the smaller engine thus would operate at a load factor distinctly higher than would the original engine, and that is how the gain would be made. For, on the basis of experimental data relating load factor and specific fuel consumption, which improves rapidly with load factor, it was estimated that the resulting increases in load factor would give gains in miles per gallon at road load varying from about 35 percent at 20 miles per hour to 20 percent at 60 miles per hour.

The data presented above on what may be obtained

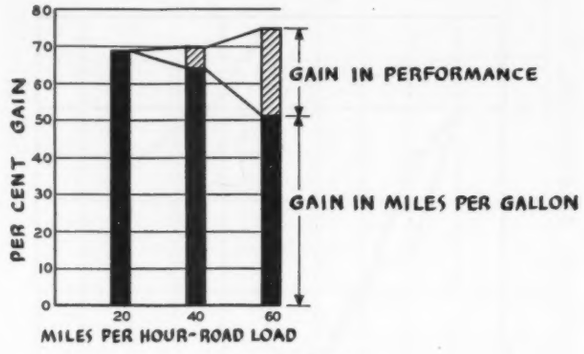

FIGURE 14
Gains with Fuel of More Than 100 Octane Number Compared with 70 Octane Number.

with high-octane fuels may or may not indicate a future trend. However, they surely do show that, with still better fuels and with automobiles engineered to fit them, it is at least technically possible to make further improvements which will be as large or larger than those made in the past decade.

Conclusion

Thus the advances achieved year by year in fuels and in cars have been made to supplement one another in such a way as to give people better products, and at lower cost. The consistent growth and success of the oil and automobile industries indicate that car users have given these improvements their enthusiastic approval. And so it seems reasonable to expect that this mutual and advantageous evolution in fuels and engines will be continued as future technical and economic advances permit.

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[2] *Ibid.,* 40 (1940).
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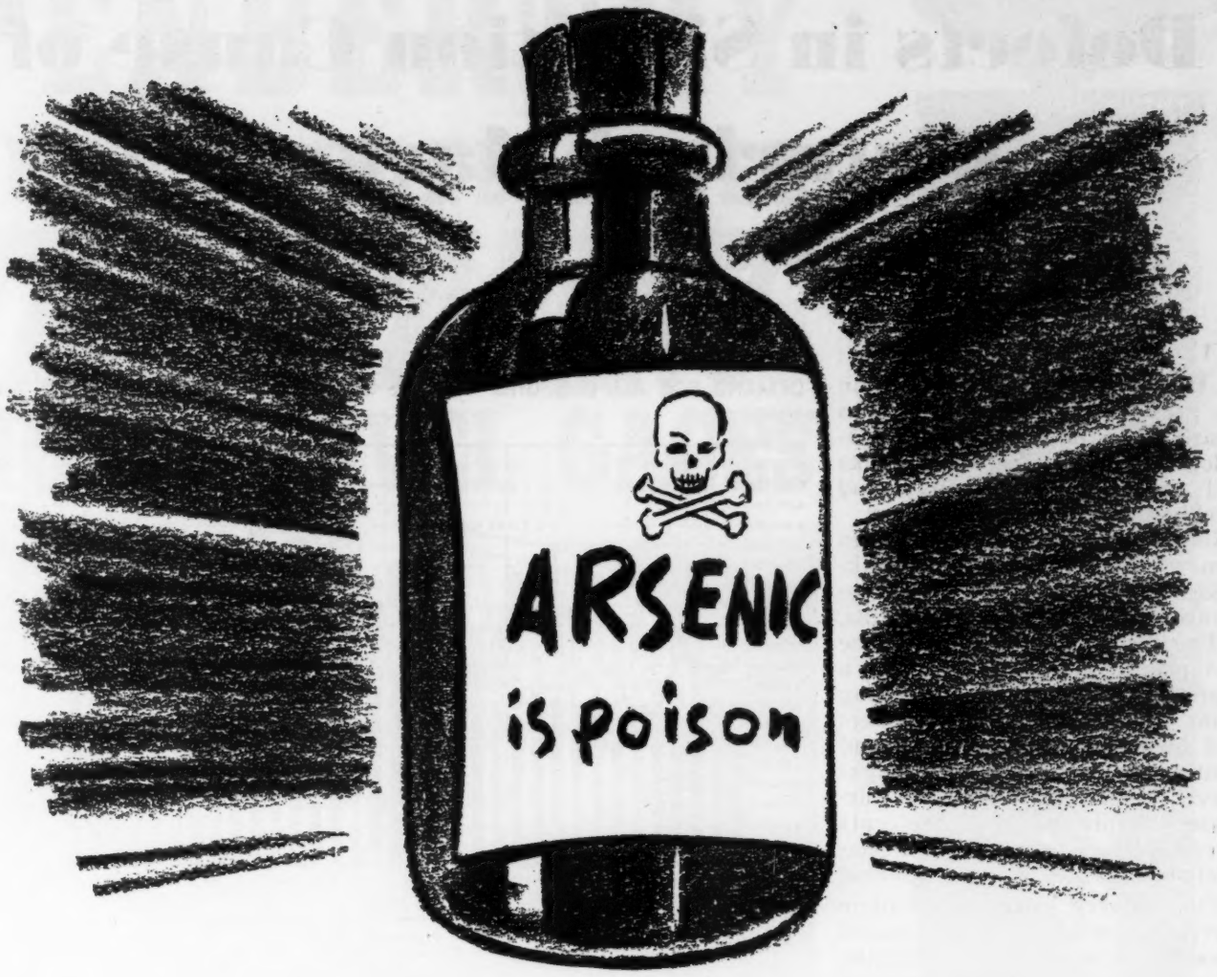

. . . to dezincification

The use of arsenic as an inhibitor of dezincification antedates the use of other practical inhibitors. Field studies and practical experiments over many years confirm the advantages of arsenic as the best available inhibitor for condenser tube dezincification.

In examining many instances of condenser tube failure during the past three years, the Revere Research Laboratories found the following:

NO. OF TUBES	FAILURE THROUGH DEZINCIFICATION
36 tubes without commercial amounts of arsenic	36
10 tubes with .02% to .06% arsenic	*none*

In addition, arsenic does *not* have undesirable effects on Admiralty metal. There is no tendency towards season-cracking or stressless intergranular corrosion.

Consider the advantage of selecting Revere Arsenical Admiralty Tubes for maximum over-all economy. Replacement costs, shut-down costs, and damage costs due to tube failure may be cut considerably by specifying Revere Arsenical Admiralty Tubes in your installations.

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Defects in Situation Cause of Disturbed Markets

L. J. LOGAN

THE strong and weak points in the present oil situation have been clearly reflected in the market developments of the past few weeks and in the latest monthly and weekly statistics of the industry.

In fact, the markets have been somewhat tardy in reflecting weaknesses that have shown up obviously in the statistics for months.

The strain that surplus gasoline had placed on the markets for a year finally reached a breaking point at the middle of October; and in Louisiana, Arkansas, and Southwest Texas, prices of high-gravity crudes were reduced. Purchasers explained that the cuts were necessary because of the relatively low market value of gasoline.

The refinery prices of gasoline currently are close to the record lows that were reached during the depression years, and in view of the exceptionally large quantities in storage, no material improvement is within sight.

In contrast, however, markets for other refined products are firm and they promise to continue so, in view of favorable situations with regard to inventories and current supply.

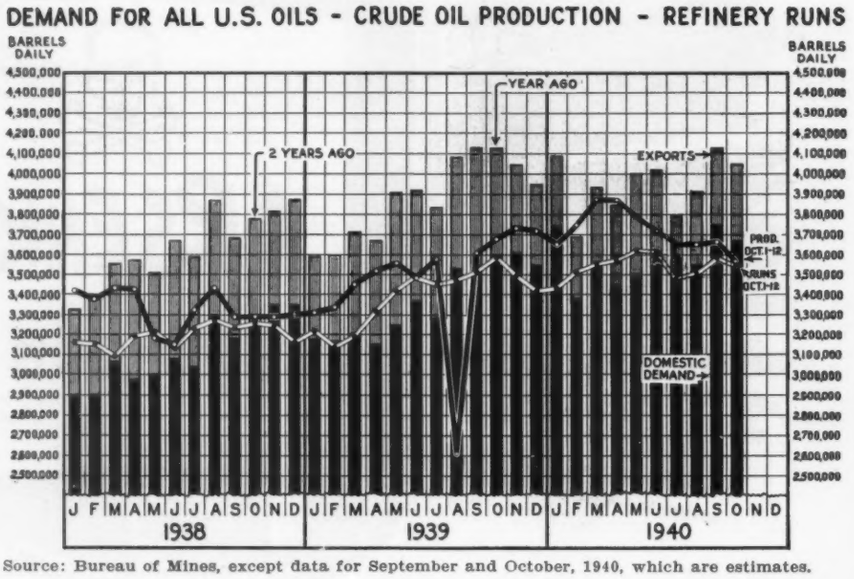
The markets for crude oil, meanwhile, are controlled by these varying situations in the refined oil markets, demand for the heavier crudes being well sustained by the large requirements for both light and heavy fuel oils, and the market for lube-stock crudes being fair, while oils rich in gasoline content are in poor demand.

This general situation led the Bureau of Mines to make the following comment in its latest monthly forecast: "The high seasonal level of both gasoline and distillate fuel oil stocks indicates the possibility of lower runs during the winter months. The selection of heavier crudes, accompanied by moderate distillate yields and low gasoline yields, seems probable if the industry attempts to meet the strong demand for residual fuel oils."

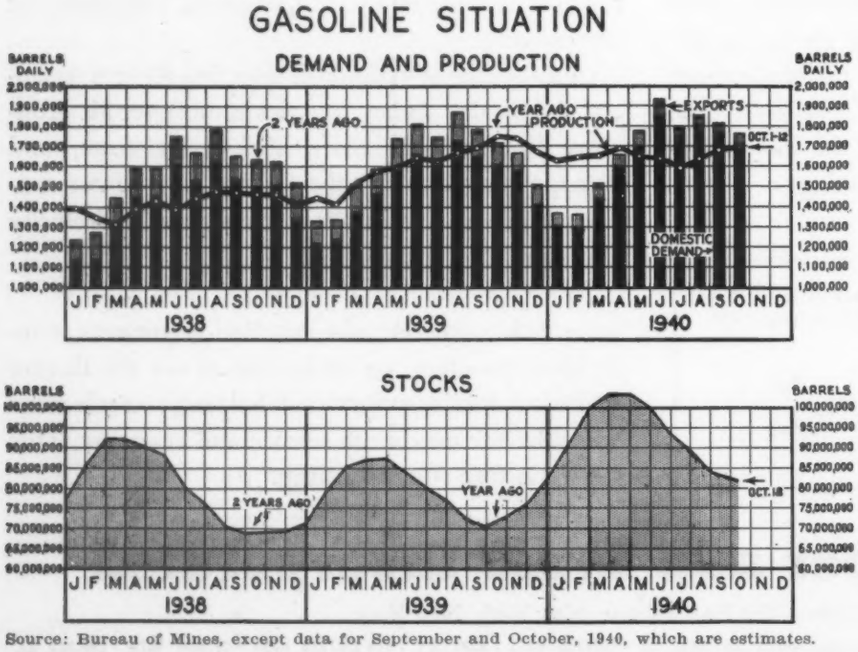
Gasoline Situation

The outlook for the gasoline market does not appear very promising even when considered in the most favorable light. There is a definite threat of the accumulation of substantial quantities in storage during the winter and of too much on hand at the end of the winter to permit firm markets during the following heavy-consuming season.

The Bureau of Mines in its latest


DEMAND FOR ALL U.S. OILS - CRUDE OIL PRODUCTION - REFINERY RUNS
BARRELS DAILY
YEAR AGO
2 YEARS AGO
EXPORTS
PROD. OCT.1-12
RUNS OCT.1-12
DOMESTIC DEMAND
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1938
1939
1940

Source: Bureau of Mines, except data for September and October, 1940, which are estimates.


GASOLINE SITUATION
DEMAND AND PRODUCTION
BARRELS DAILY
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1938
1939
1940

Source: Bureau of Mines, except data for September and October, 1940, which are estimates.

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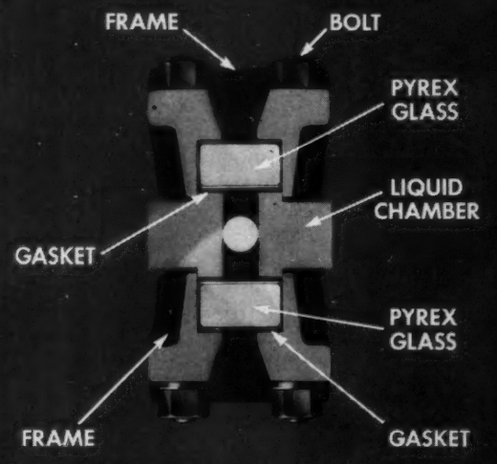
To observe the color or density of liquids under high pressures and/or temperatures



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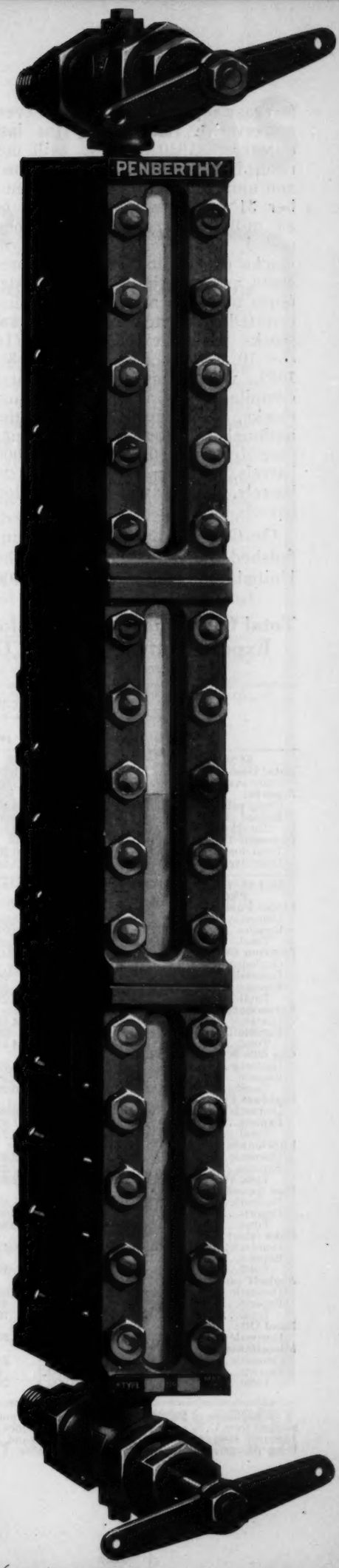
These gages are available in any length and for various pressures and temperatures. We shall be glad to quote upon your requirements. Write for new Catalog 34-A.



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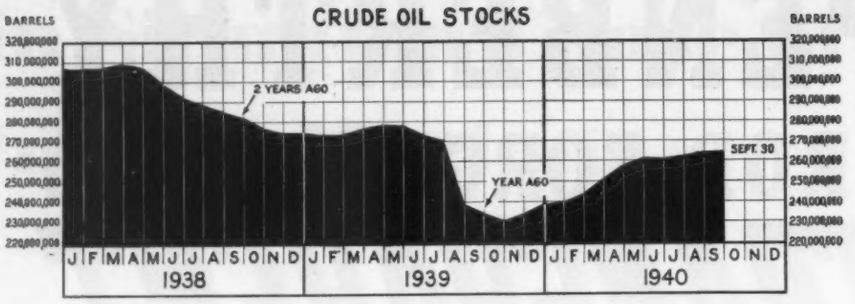
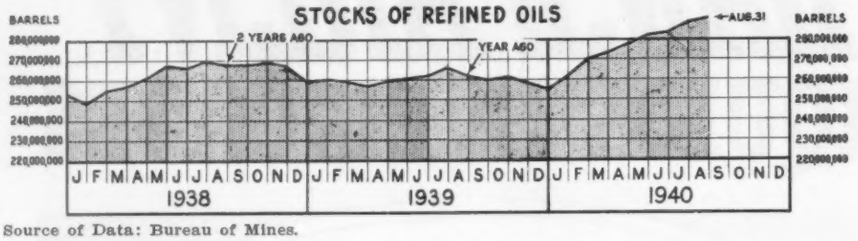
forecast report stated: ". . . even conservative runs during the last quarter of 1940 probably will not result in reducing stocks of finished and unfinished gasoline by December 31 below last year's level of 83 million barrels." The agency added, "However, the increase in stocks of aviation gasoline represents an essential reserve for defense purposes and should be discounted in comparisons of total stocks with previous years." (In the 10 months from October 31, 1939, when statistics were first compiled on aviation gasoline stocks, to August 31, 1940, the national inventory of that product rose from 2,400,000 to 3,821,000 barrels, an increase of 1,421,000 barrels, or an average of 142,100 barrels monthly.)





Source of Data: Bureau of Mines.

On October 19, finished and unfinished gasoline stocks in the United States totaled 81,656,000 barrels, according to the American Petroleum Institute. That was 9,238,000 barrels, or 12.7 percent, more than the 72,418,000 barrels on hand at the corresponding time last year.

Economists have estimated that as little as 85,000,000 barrels of gasoline in storage would be adequate as operating stocks on March 31, 1941. Consequently, the industry faces an extremely difficult task if it is to hold the gasoline inventory anywhere near the economically desirable level as of the end of the winter.

Basing calculations on the assumption that refiners will take comparatively large yields of heating oils from crude during the fall and winter and at the same time subnormal yields of about 43 percent of gasoline, petroleum economists have figured that gasoline stocks could be held down to the 85,000,000-barrel economic level as of March 31 by limiting crude runs to stills to an average of 3,400,000 barrels daily between September 30, 1940, and March 31, 1941.

In the first 19 days of October, refinery runs actually averaged 3,544,000 barrels daily, or 144,000 barrels more than the indicated desirable average. In the week ended October 19, the runs averaged 3,525,000 barrels daily, having been reduced 30,000 barrels from the rate of the two previous weeks.

Attainment of the 85,000,000-barrel level for gasoline stocks at the end of the winter, by limiting refinery runs as above indicated, would require the holding of crude production to an average of about 3,525,000 barrels daily, it is calculated, as about 125,000 barrels of domestic crude daily will be used in the oil fields and for other purposes.

Crude oil production in the first

Total Oil Demand Drops Below 1939 Curve, as Curtailment of Exports Outweighs Small Gain in Domestic Consumption

Figures indicate barrels, and are from Bureau of Mines

	AUGUST			FIRST EIGHT MONTHS		
	1939	1940	Percent Change	1939	1940	Percent Change
SUMMARY—						
Total Demand	125,704,000	121,130,000	— 3.6	919,866,000	951,690,000	+ 3.5
Daily average	4,055,000	3,907,000	— 3.6	3,785,000	3,900,000	+ 3.0
Exports:						
Crude petroleum	5,969,000	4,170,000	— 30.1	48,222,000	36,192,000	— 24.9
Refined products	11,429,000	6,760,000	— 40.9	79,934,000	56,695,000	— 29.1
Total exports	17,398,000	[1]10,930,000	— 37.2	128,156,000	92,887,000	— 27.5
Domestic Demand:						
Total domestic demand	108,306,000	110,200,000	+ 1.7	791,710,000	858,803,000	+ 8.5
Daily average	3,494,000	3,555,000	+ 1.7	3,258,000	3,520,000	+ 8.0
TOTAL DEMAND FOR PRODUCTS						
Motor Fuel:						
Domestic	53,828,000	55,346,000	+ 2.8	362,554,000	387,833,000	+ 6.9
Exports	4,208,000	[2]2,087,000	— 50.4	31,188,000	16,863,000	— 45.9
Total	58,036,000	57,433,000	— 1.0	393,742,000	404,696,000	+ 2.8
Aviation Gasoline (Included above):						
Domestic	[4]	666,000	.....	[4]	3,757,000	.....
Exports	221,000	569,000	+ 157.5	3,093,000	2,671,000	— 13.6
Total	.....	1,235,000	.....	.....	6,428,000	.....
Kerosene:						
Domestic	4,436,000	4,114,000	— 7.3	38,208,000	43,419,000	+ 13.6
Exports	841,000	230,000	— 72.7	5,340,000	2,748,000	— 48.5
Total	5,277,000	4,344,000	— 17.7	43,548,000	46,167,000	+ 6.0
Gas Oils & Distillate Fuels:						
Domestic	8,157,000	8,732,000	+ 7.0	86,314,000	103,032,000	+ 19.4
Exports	3,361,000	1,469,000	— 56.3	22,136,000	14,632,000	— 33.9
Total	11,518,000	10,201,000	— 11.4	108,450,000	117,664,000	+ 8.5
Residual Fuel Oils:						
Domestic	25,407,000	25,897,000	+ 1.9	204,781,000	216,754,000	+ 5.8
Exports	1,613,000	1,815,000	+ 12.5	12,134,000	10,912,000	— 10.1
Total	27,020,000	27,712,000	+ 2.6	216,915,000	227,666,000	+ 4.9
Lubricants:						
Domestic	1,963,000	2,024,000	+ 3.1	14,998,000	15,701,000	+ 4.7
Exports	1,204,000	727,000	— 39.6	7,484,000	8,227,000	+ 9.9
Total	3,167,000	2,751,000	— 13.3	22,482,000	23,928,000	+ 6.4
Wax (pounds):						
Domestic	20,503,000	41,897,000	+ 104.3	168,422,000	219,115,000	+ 30.1
Exports	14,673,000	8,968,000	— 38.8	156,286,000	147,766,000	— 5.5
Total	35,176,000	50,865,000	+ 44.6	324,708,000	366,881,000	+ 12.9
Coke (short tons):						
Domestic	168,800	117,400	— 30.5	927,700	907,100	— 2.2
Exports	25,400	36,200	+ 42.5	173,800	173,300	— 0.3
Total	194,200	153,600	— 20.9	1,101,500	1,080,400	— 1.9
Asphalt (short tons):						
Domestic	642,200	672,400	+ 4.7	3,114,600	3,215,900	+ 0.3
Exports	3,300	[3]32,000	+ 869.7	30,100	214,700	+ 613.3
Total	645,500	704,400	+ 9.1	3,144,700	3,430,600	+ 9.1
Road Oil:						
Domestic	1,576,000	1,553,000	— 1.5	5,914,000	5,569,000	— 5.8
Miscellaneous:						
Domestic	211,000	242,000	+ 14.7	1,506,000	1,357,000	— 9.9
Exports	4,000	43,000	+ 975.0	60,000	739,000	+1131.7
Total	215,000	285,000	+ 32.6	1,566,000	2,096,000	+ 33.8

[1] Exclusive of 22,000 barrels exported from non-contiguous territories, but inclusive of 1,181,000 barrels shipped from U. S. to territories. [2] Includes benzol, 9,000 barrels in August, 1940. [3] Beginning January, 1940, includes both manufactured and unmanufactured asphalt; only unmanufactured asphalt being previously shown. [4] Not available.

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19 days of October actually averaged 3,611,000 barrels daily, or 86,000 barrels more than the average just mentioned as desirable for the fall and winter. The output in the week ended October 19 averaged 3,667,550 barrels daily. That was 142,000 barrels more than the desirable average and 26,000 barrels more than the daily average of the preceding week.

No material change has occurred in the trend of demand for gasoline. For November the Bureau of Mines estimated total demand 5.6 percent higher than the actual of November last year, an increase about in line with gains of the earlier months of 1940. Exports were estimated up 100,000 barrels from October, although 34 percent down from November, 1939, reports from principal shippers having indicated expectations of movement of about 1,700,000 barrels to other countries. The total demand for gasoline in November therefore was estimated up 3.5 percent over November, 1939.

Changes From Year Ago in Stocks of Crude and Refined Oils in the United States

(Figures indicate barrels)

LATEST WEEKLY DATA

(Sources: Crude stocks, Bureau of Mines; all other figures American Petroleum Institute.)

STOCKS OF:	October 19, 1939	October 19, 1940	Percent Change
Gasoline	72,418,000	81,656,000	+12.7
Gas Oil & Distillate	39,337,000	49,051,000	+24.7
Residual Fuel Oil	114,052,000	108,141,000	— 5.2
Crude Oil	[1]229,870,000	[2]261,511,000	+13.7

LATEST MONTHLY DATA

(Source: Bureau of Mines.)

ITEM	Stocks at End of August		
	1939	1940	Percent Change
SUMMARY—			
Crude Petroleum:			
Refinable in U. S.	238,479,000	264,252,000	+10.8
Heavy in California	14,253,000	12,798,000	—10.2
Natural Gasoline	6,624,000	7,702,000	+16.3
Refined Products	276,546,000	290,778,000	+ 5.1
Total, all oils	535,902,000	575,530,000	+ 7.4
Day's supply:			
August Basis	132	147	+11.4
8 Months Basis	142	148	+ 4.2
PRODUCTS—			
Gasoline:			
Finished	66,448,000	77,134,000	+16.1
Unfinished	5,887,000	6,567,000	+11.6
Total	72,335,000	83,701,000	+15.7
Aviation Gasoline (included above)	[3]	3,821,000	.....
Kerosene	9,361,000	9,476,000	+ 1.2
[4]Gas Oil & Distillate Fuels	29,282,000	33,964,000	+15.9
[4]Residual Fuel Oils	95,897,000	87,617,000	— 8.6
Lubricants	7,069,000	8,457,000	+19.6
Wax (pounds)	108,173,000	112,359,000	+ 3.9
Coke (short tons)	682,000,000	647,000,000	— 5.1
Asphalt (short tons)	529,500,000	588,000,000	+11.0
Road Oil	985,000	892,000	— 9.4
Miscellaneous	282,000	379,000	+34.4
Other Unfinished Oils	40,819,000	41,541,000	+ 1.8

[1] October 14, 1939.
[2] October 12, 1940.
[3] Not available.
[4] At refineries only.

Oil Exports Down 19 Percent in First Year of War, and Off 37 Percent in August

ITEM	TWELVE MONTHS PERIOD			MONTH OF AUGUST		
	Ended Aug. 31, 1939	Ended Aug. 31, 1940	Percent Change	1939	1940	Percent Change
Crude Oil	71,064,000	60,047,000	— 15.5	5,969,000	4,170,000	— 30.1
Products:						
Motor Fuel	48,363,000	30,234,000	— 37.5	4,208,000	[6]2,087,000	— 50.4
Aviation Gasoline (included above)	[1]3,093,000	[2]3,604,000	+ 16.5	221,000	569,000	+ 157.5
Kerosene	7,968,000	5,451,000	— 31.6	841,000	230,000	— 72.7
Gas Oil and Distillate	30,821,000	24,517,000	— 20.4	3,361,000	1,469,000	— 56.3
Residual Fuel Oil	18,464,000	16,268,000	— 11.9	1,613,000	1,815,000	+ 12.5
Lubricants	10,426,000	12,724,000	+ 22.0	1,204,000	727,000	— 39.6
Wax (pounds)	241,208,000	224,144,000	— 7.1	14,673,000	8,968,000	— 38.9
Coke (short tons)	248,400	271,200	+ 9.2	25,400	36,200	+ 42.5
Asphalt (short tons)	48,200	[3]527,200	.....	3,300	32,000	.....
Miscellaneous Oils	99,000	802,000	+ 710.1	4,000	43,000	+ 975.0
[4]Total Refined Products	117,530,000	93,177,000	— 20.7	11,429,000	[5]6,760,000	— 40.9
Total Crude and Products	188,594,000	153,224,000	— 18.8	17,398,000	[5]10,930,000	— 37.2

[1] September, October, November, 1938, not included. [2] September, 1939, not included. [3] Beginning January, 1940, includes both manufactured and unmanufactured asphalt; only unmanufactured asphalt being previously shown. [4] Not the sum of the above figures, some of which do not indicate barrels. [5] Exclusive of 22,000 barrels exported from non-contiguous territories, but inclusive of 1,181,000 barrels shipped from U. S. to territories. [6] Includes benzol, 9,000 barrels in August, 1940.

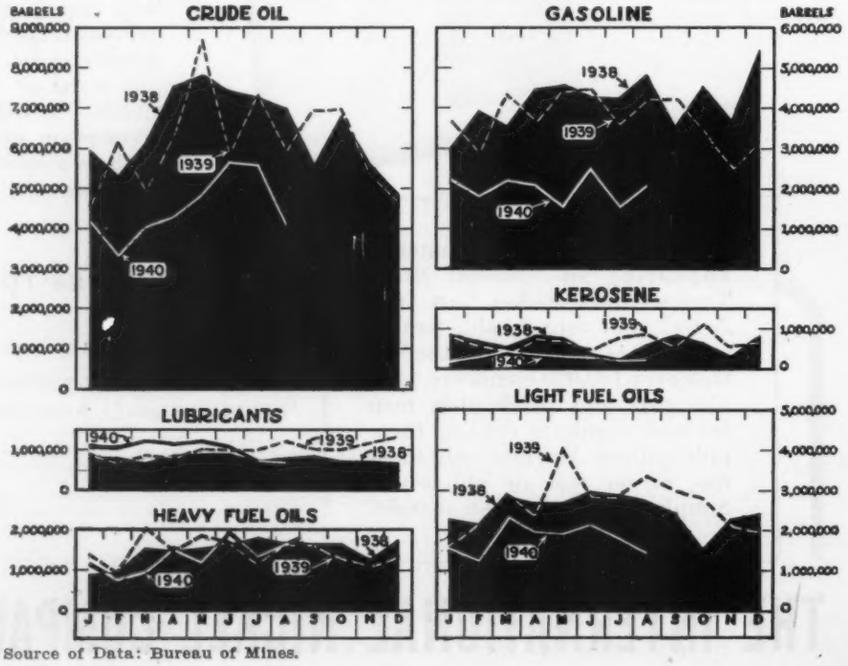
For October, the bureau had estimated that domestic demand for motor fuel would be 7 percent larger than a year previously, that exports would total 1,600,000 barrels, and that total demand would be 2.8 percent larger than in October, 1939.

Actual figures on gasoline demand are available only through August, and in that month, comparative figures were not normal, because of pre-tax buying in June, which may have tended to reduce refinery shipments in August, and because August, 1939, was an exceptional month in heavy consumption of gasoline. Therefore, domestic demand was only 2.8 percent larger in August, 1940, than in August, 1939, a gain less than half the average of the earlier months of this year. Exports, meanwhile, where one half as large as a year before, and total demand for gasoline showed a decrease of 1 percent from August, last year.

For the first 8 months of 1940 in the aggregate, domestic demand for gasoline was 6.9 percent larger than in the corresponding months of 1939. But with exports down 46 percent, total demand showed a gain of only 2.8 percent.

Being the industry's principal product, gasoline largely determines the trend of demand for all oils, and in August, 1940, the total

U. S. Exports of Crude Petroleum and Refined Products

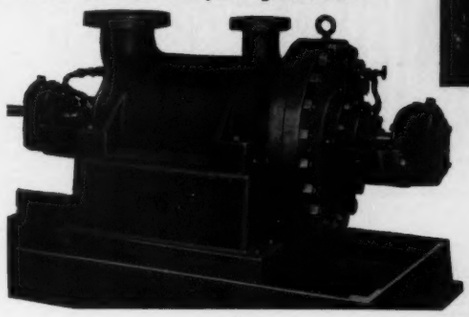


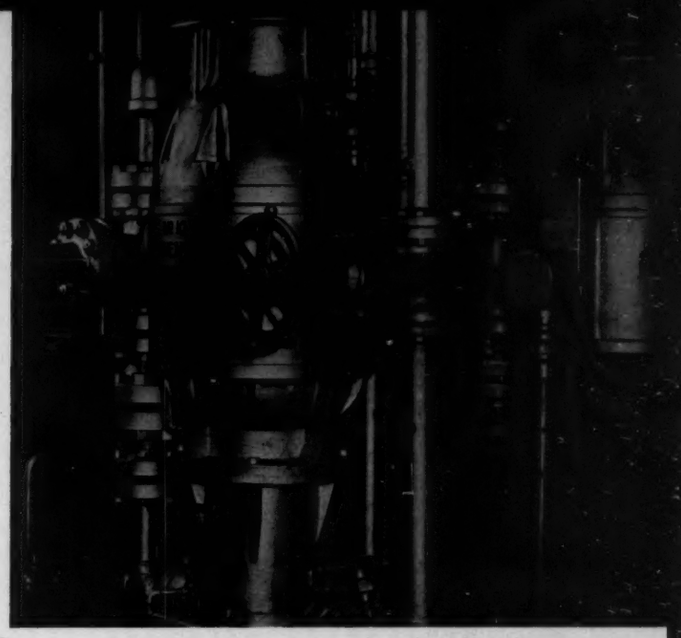
Source of Data: Bureau of Mines.

WHATEVER YOUR PUMPING PROBLEMS MAY BE, HERE ARE PUMPS TO SOLVE THEM!

The HOUDRY PROCESS PUMP is a recent development for circulating molten salts (at temperatures up to 850 degrees) as a heat transfer agent to the catalytic chests. A problem of handling thousands of gallons per minute at such high temperatures was solved by Byron Jackson Engineers, and many pumps, illustrated at left, are now in successful operation.

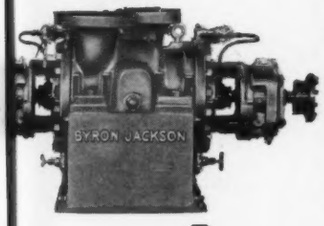
You are invited to consult freely with Byron Jackson Co. regarding any fluid handling problems. Such engineering development work is held in strict confidence, and preliminary conferences can be arranged without expense or obligation on your part.



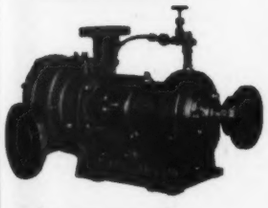


(Left): MHO DOUBLE CASE Hot Oil Charging Pumps are ideal for "medium pressure" service where pressures are too high for a pump of single case construction, but not high enough to require the well known Byron Jackson Type HO Pump. A new Condensed Catalog gives complete information on both of these successful pumps.

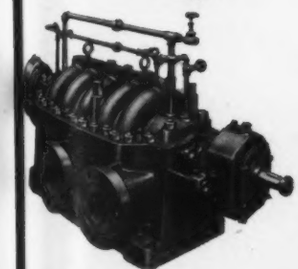
(Above): HYDROPRESS Pumps are designed for capacities as low as 15 g.p.m., and heads as high as 10,000 feet. Used above as a Naphtha Quench Pump discharging 50 g.p.m. at 140 degrees F., discharge pressure 900 lbs. per sq. inch.



VC 2-STAGE Hot Oil Pumps have circular center suspension, concentric with the shaft, which permits them to operate without expansion misalignment in pumping hot oil at temperatures up to 850 degrees F. The 2-stage type pictured handles from 20 to 5,500 g.p.m. against heads to 900 feet; a single stage type is for smaller capacities, and heads to 450 feet.

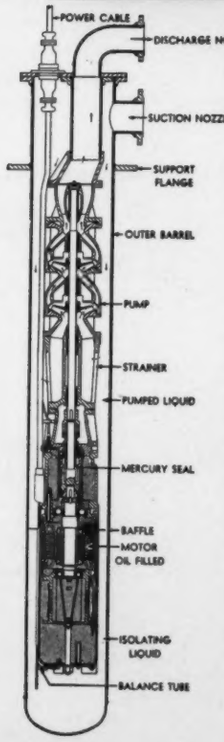


BM PROCESS PUMPS have only one stuffing box—a desirable feature possible only with overhung impeller construction. Since this stuffing box operates at slightly more than suction pressure, the unit is well adapted to vacuum service. These pumps are especially suited for pumping liquids which are difficult to hold in a stuffing box. Capacity range: 10-7,000 g.p.m.; Head Range: 20 to 500 feet.



BYRON JACKSON MULTIPLEX Pumps are suited for cold or warm oil pumping. Correct design and rugged construction assure long, trouble-free service, handling capacities up to 75,000 barrels per day against pressures up to 1,200 pounds per square inch.

BILTON Pumps are single stage, single suction units, with the close-coupled motor and pump having a common shaft carried on ball bearings. It operates in any position, and is the handiest pump ever developed for general cold or warm pumping. Capacity Range: 10-1,500 g.p.m.; Head Range: 10-300 feet.



(Above): STUFFINGBOXLESS PUMPS have *no packing* and *no stuffing boxes* and are ideally suited for propane, butane, gasoline and other highly volatile liquids. The view above shows two STUFFINGBOXLESS Pumps operating successfully in a modern, major refinery, handling a highly volatile hydrocarbon at 225 lbs. suction and 375 lbs. discharge pressure. View at left shows details of design. An illustrated Bulletin, giving all details, will be sent at your request.

(Left): SUBMERSIBLE Pumps meet every requirement for refinery water supply; see second view at left. An electric motor, direct-connected to an efficient Byron Jackson Deepwell Turbine Pump, is sealed in a steel case filled with dielectric oil, and the complete unit is submerged in the water being pumped. Power is carried down the well to the motor by a submarine cable, with only a weather-proof, tamper-proof metal switchbox on the surface. Control may be local or remote—manual or automatic. The submerged motor eliminates any sparking hazard, and a continuous, low-cost water supply is assured. Descriptive bulletin, with large 4-color cross-section view, is available on request.

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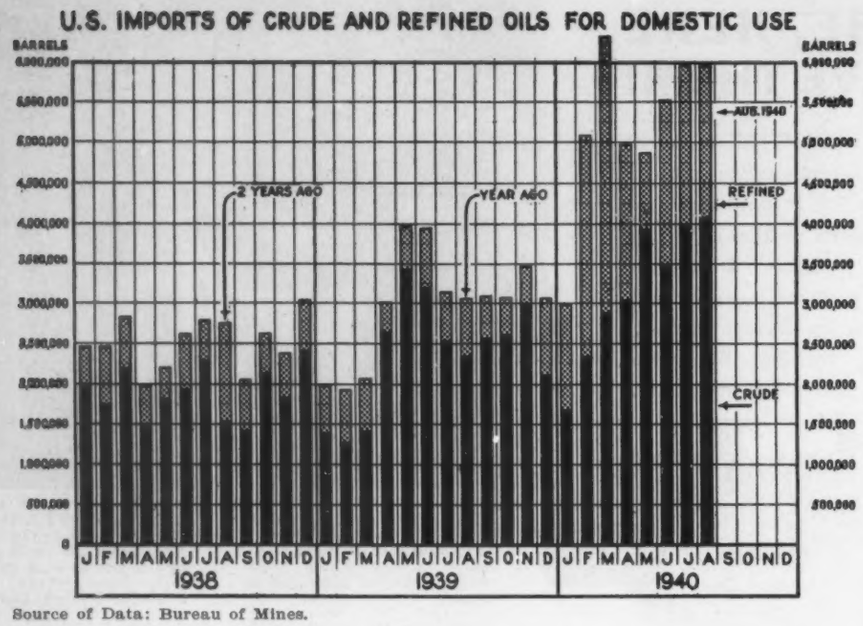
U.S. IMPORTS OF CRUDE AND REFINED OILS FOR DOMESTIC USE
BARRELS
2 YEARS AGO
YEAR AGO
AUG. 1940
REFINED
CRUDE
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1938
1939
1940

Source of Data: Bureau of Mines.

demand was 3.6 percent smaller than in August, 1939. Domestic consumption was up 1.7 percent, but total exports were down 37 percent, with shipments of crude off 30 percent and those of refined products down 41 percent.

While demand for gasoline was subnormal in August, kerosene requirements also were comparatively small, as domestic use was off 7 percent, while exports were down from 841,000 barrels a year previously to 230,000 barrels, making total demand off nearly 18 percent.

Light fuel oils were used in 7 percent larger volume in August, 1940, than in August, 1939, in the United States, but with exports down from 3,361,000 to 1,469,000 barrels, total demand showed an 11 percent decrease.

For heavy fuel oils the record was better, as domestic use was up 2 percent and exports were 12 percent higher, indicating a gain of 2.6 percent in total demand.

Domestic demand for lubricants was up 3 percent in August, but exports were down from 1,204,000 to 727,000 barrels, and total demand was off 13 percent.

For the first 8 months of 1940, total demand upon the oil industry of the United States was 951,690,000 barrels, or exactly 3,900,000 barrels daily, on the average, an increase of 3 percent over the daily average for the corresponding months of 1939. Domestic consumption was up 8 percent, on a daily average basis, having totaled 858,803,000 barrels. Total exports were down 27.5 percent, with shipments of crude off 25 percent and those of refined products down 29 percent.

Total demand for kerosene was up 6 percent for the 8 months, with domestic use 13.6 percent larger and exports down 48.5 percent. Light fuel oils were required in 8.5 percent increased quantity, as domestic consumption was up 19 percent and foreign shipments were down 34 percent. Total market for heavy fuel oil was up approximately 5 percent, as a 5.8 percent gain in domestic use was offset only by a 10 percent decline in exports. The total demand for lubricants was 6.4 percent greater in the first 8 months of 1940 than in the like months of 1939, with domestice consumption up 4.7 percent and exports 10 percent larger.

Summary of Bureau of Mines Forecasts for November, 1940

Barrels

	Forecast November, 1940	Forecast October, 1940	Actual November, 1939
Demand for Motor Fuel:*			
Domestic demand	49,900,000	53,000,000	47,275,000
Exports	1,700,000	1,600,000	2,560,000
	51,600,000	54,600,000	49,835,000
Supply of Motor Fuel:			
Straight-run and cracked gasoline production	45,180,000	46,830,000	48,036,000
Natural gasoline used at refineries	4,220,000	4,350,000	4,286,000
Total refinery production	49,400,000	51,180,000	52,322,000
Benzol and other natural gasoline	1,300,000	1,320,000	930,000
Imports	.....	.....	86,000
Decrease in finished stocks	900,000	2,100,000	.....
Increase in finished stocks	.....	.....	3,503,000
Available supply	51,600,000	54,600,000	49,835,000
Crude Oil Requirements:			
Percent yield of gasoline from crude	43.4	43.4	45.79
Refinery crude required	104,100,000	107,900,000	104,916,000
Daily average	3,470,000	3,480,600	3,497,000
Foreign crude runs	3,400,000	3,500,000	2,234,000
Exports	3,900,000	3,900,000	5,323,000
Fuel and losses	2,500,000	2,700,000	1,972,000
Total demand for domestic crude	107,100,000	111,000,000	109,977,000
Daily average	3,570,000	3,580,600	3,665,900
Increase in domestic stocks	.....	.....	1,910,000
Actual production	.....	.....	111,887,000
Daily average	.....	.....	3,729,600

* The term "Motor Fuel" as used in this report includes gasoline, naphtha, and benzol used for all purposes, but does not include heavier distillates used in the operation of tractors or burned in Diesel engines.

Oil Imports for Domestic Use Up Sharply

Figures indicate barrels and are from Bureau of Mines.

MONTH	Crude Oil	Refined Products	Total
January:			
Jan., 1939	1,373,000	609,000	1,982,000
Jan., 1940	1,664,000	1,321,000	2,985,000
Change	+21.2%	+117.1%	+52.0%
February:			
Feb., 1939	1,266,000	654,000	1,920,000
Feb., 1940	2,343,000	2,731,000	5,074,000
Change	+85.0%	+320.0%	+164.0%
March:			
Mar., 1939	1,404,000	659,000	2,063,000
Mar., 1940	2,895,000	3,410,000	6,305,000
Change	+106.2%	+417.4%	+205.6%
April:			
April, 1939	2,648,000	366,000	3,014,000
April, 1940	3,041,000	1,948,000	4,989,000
Change	+14.8%	+432.0%	+65.5%
May:			
May, 1939	3,434,000	529,000	3,963,000
May, 1940	3,921,000	934,000	4,855,000
Change	+14.2%	+76.5%	+22.5%
June:			
June, 1939	3,196,000	750,000	3,946,000
June, 1940	3,488,000	2,056,000	5,544,000
Change	+9.1%	+174.1%	+40.5%
July:			
July, 1939	2,539,000	608,000	3,147,000
July, 1940	3,981,000	2,000,000	5,981,000
Change	+56.8%	+228.9%	+90.0%
August:			
Aug., 1939	2,346,000	717,000	3,063,000
Aug., 1940	4,074,000	1,898,000	5,972,000
Change	+73.7%	+164.7%	+95.0%
1st 8 Months:			
1939	18,206,000	4,765,000	22,971,000
1940	25,407,000	16,218,000	41,625,000
Change	+39.6%	+240.6%	+81.4%

National Defense Is A.P.I. Program

National defense was the foremost theme of the general sessions of the twenty-first annual meeting of the American Petroleum Institute, Chicago, November 11-15. The Division of Refining held three sessions, and the papers presented make up the technical section of REFINER AND NATURAL GASOLINE MANUFACTURER this month. All institute officials were reelected. San Francisco was selected for the annual meeting November 3-7, 1941, while the mid-year meeting will be held in Fort Worth, May 19-23.

Officials are Axtell J. Byles, New York, president; William R. Boyd, Jr., New York, executive vice president; George A. Hill, Jr., Houston Oil Company of Texas, Houston, vice president for production; J. Howard Pew, Sun Oil Company, Philadelphia, vice president for refining; E. V. Weber, Eureka Oil Company, Cincinnati, vice president for marketing; Lacey Walker, New York, secretary and assistant treasurer; O. D. Donnell, The Ohio Oil Company, Findlay, Ohio, treasurer, and J. S. Cooke, New York, assistant secretary.

Changes in the executive committee included selection of H. D. Collier, Standard Oil Company of California, San Francisco, to succeed the late W. H. Berg of the same company, and election of Reese Taylor, Union Oil Company of California, to succeed L. B. Simmons, Rock Island Refining Company, Duncan, Oklahoma.

Fifty-five vacancies on the board of directors were filled by election of five new members and reelection of 50. New members are A. S. Russell, Standard Oil Company of California, who will serve the term of the late W. H. Berg of the same company; Henry L. Phillips, Sinclair Prairie Oil Company, Tulsa, who succeeds J. A. Vickers, Vickers Petroleum Company, Wichita, who died November 11; C. L. Henderson, Vickers Petroleum Company, Wichita, who takes the place of L. B. Simmons, Rock Island Refining Company, in the central production group; and two men for the supply group, W. L. Childs, Reed Roller Bit Company, Houston; Percy C. Jones, S. M. Jones Company, Toledo; and two in the at-large group, Ralph B. Lloyd, Lloyd Corporation, Los Angeles, and Parker Melvin, Pennsylvania Grade Crude Oil Association, Bradford.

Central Committee

The 20 members of the central committee of the Division of Refining were elected at its final meeting, November 14. They are: C. R. Barton, Tide Water Associated Oil Company, New York; W. F. Burt, Socony-Vacuum Oil Company, New York; Oscar Cordell, Bareco Refining Company, Tulsa; E. D. Cumming, Shell Oil Company, St. Louis; A. D. David, Bradford-Penn Refining Company, Clarendon, Pennsylvania; Bert Fisher, Kendall Refining Company, Bradford; J. L. Hanna, Standard Oil Company of California, San Francisco; G. W. Hanneken, Standard Oil Company of Ohio, Cleveland; M. Halpern, The Texas Company, New York; A. M. Kelley, Richfield Oil Corporation, Los Angeles; W. W. Lowe, Cities Service Oil Company, New York; T. M. Martin, Lion Oil Refining Company, El Dorado, Arkansas; Walter Miller, Continental Oil Company, Ponca City; G. G. Oberfell, Phillips Petroleum Company, Bartlesville; M. G. Paulus, Standard Oil Company (Indiana) Chicago; A. E. Pew, Jr., Sun Oil Company, Philadelphia; W. A. Slater, Gulf Oil Corporation, Pittsburgh; C. F. Smith, Standard Oil Company of New Jersey, New York; G. H. Taber, Jr., Sinclair Refining Company, New York, and C. B. Watson, The Pure Oil Company, Chicago.

Five additional committee members were appointed by the president: Paul G. Blazer, Ashland Refining Company, Ashland, Kentucky; C. L. Henderson, Vickers Petroleum Company, Wichita; E. J. Henry, Atlantic Refining Company, Philadelphia; Roy B. Jones, Panhandle Refining Company, Wichita Falls; and W. L. Stewart, Jr., Union Oil Company of California, Los Angeles.

Announcement of safety awards at the first general session revealed that the force at the Baton Rouge plant of Standard Oil Company of Louisiana had set a world's record of 4,216,600 hours worked without a disabling accident over a period of 203 days between January 13 and August 3. Other safety awards within the manufacturing division of the industry went to refining plants of the American Petroleum Company, Houston, and the Standard Oil Company of Texas, Houston, and in natural gasoline to Shell Oil Company, St. Louis; General Petroleum Corporation, Los Angeles; Shell Oil Company, San Francisco; Hope Construction & Refining Company, Pittsburgh, and United Gas Pipe Line Company, Shreveport.

The board of directors passed two resolutions, one pledging support of the industry to the program of national defense, and the other recommending continuation of national legislation under which the Interstate Oil Compact Commission exists.

In the absence of Axtell J. Byles, president, William R. Boyd, Jr., executive vice president, gave the address scheduled as that of the president. Other speakers on the first general session program were T. H. Barton, Lion Oil Refining Company, El Dorado, Arkansas, and Dr. Robert R. Wilson, petroleum section, Raw Materials Division, Commission of National Defense, Washington.

The second general session, November 14, brought William J. Cameron, Ford Motor Company, Dearborn, Michigan; H. W. Prentis, National Association of Manufacturers, New York, and Martin Dies, member of Congress, Orange, Texas.

Wilson recommended only a limited expansion of storage facilities, thus outlined:

"In order to be prepared to meet emergency demands at uncertain locations and to protect its customers from possible interruptions of transportation, it appears that the industry in general should increase its storage facilities, particularly along the eastern seaboard, and should count on carrying somewhat larger stocks than would otherwise be considered adequate.

"The adequate protection of such storage facilities from possible bombing attack is a matter that has given concern to both federal and state agencies. At our request, the American Petroleum Institute has appointed a number of regional committees to study this question and to confer with the Army and Navy representatives in the various areas, both from the standpoint of protecting the industry's supplies and of protecting congested areas or harbors from the results of possible attack."

Barton on Oil and Defense

T. H. Barton used the title "Oil and Defense," and reviewed the spirit and efforts of the petroleum industry to serve the public in peace time, which he translated as evidence that the industry is prepared to do its share in defense, saying:

"My answer is that the petroleum industry is in the best position of any basic industry to serve her country in defense.

"The petroleum industry is geared in every way to meet today's and future emergencies in the spirit which characterizes it, in the conditioning to which its previous activities have subjected its members, in the position it holds in the national economic structure, in its technological advancements, in its productive facilities, in its reserves."

Boyd Outlines Purposes

Boyd presented purposes, objectives and accomplishments of the Institute as a trade association. Concerning the Institute and its methods, he said:

"Believe me when I say to you, without equivocation or mental reservation that the American Petroleum Institute has not and is not now engaged in conducting any illegal or collusive activity. Nor do we believe that by any

The Look Box

CONVENTIONS

DEC. 2- 6	American Institute of Chemical Engineers, New Orleans.
9-14	National Asphalt Conference, Dallas.
11-15	National Chemical Exposition, Stevens Hotel, Chicago.
JAN. 6-10	Society of Automotive Engineers, Book-Cadillac Hotel, Detroit.
MAR. 3- 7	American Society for Testing Materials, Hotel Mayflower, Washington.
APR. 23-25	Petroleum Industry Electrical Association, Tulsa.
23-25	Natural Gasoline Association of America, Baker Hotel, Dallas.

stretch of fact it can be proved by competent testimony in any court of justice that the Institute has ever so engaged. I believe the institute is observing scrupulously all legal restrictions."

Contributions of the Institute to technological improvement within the industry were set out as evidence of accomplishment. Likewise, he singled out instances of cooperation between the Institute and agencies of the federal government. He spoke of the committees which will assist in providing protection for stored gasoline and said that much of the organization's activity is carried out through its divisions and committees. Again he stressed the fact that these committees adhere to rigid programs, saying:

"Let it be said, truly, that the large number of committees of the Division of Production do not discuss nor deal with quantities of crude oil produced or stored or the price asked or paid therefor. Likewise, let it be said, truly, that committees of the Division of Refining do not discuss nor deal with quantities of products refined or stored or the price asked or received therefor."

In his remarks under the title, "The Citadels of National Defense," Prentis outlined the attitude of industry, and made a plea for an attitude from government which will permit business to have its share in the program. He summed up the attitude of business with:

"Industry is opposed to war not only on humanitarian but on economic and patriotic grounds, as well. It thrives on the arts of peace. In very truth it would beat 'Swords into plowshares and spears into pruning hooks' because it knows that all war is waste. Only through the production of more peace-time goods and services can the returns of industry be increased, and the fundamental objectives of industry be attained—the elevation of standard of living of all our people to higher and higher levels.

Asks Head for Commission

"But with madmen running amuck in the world, American industry knows also the vital part it must quickly play if the tidal waves of war now overwhelming Europe and Asia are to be kept from the peaceful shores of the Western Hemisphere. Twentieth century war is not primarily warfare between men. It is the combat of iron men—warfare of machines and mass production. The Germans, it is reliably reported, conquered all of Western Europe with only 300,000 soldiers actively engaged, of whom but 40,000 were killed. Machines, not soldiers, create and support the modern prototypes of those ancient scourges of God—Genghis Kahn, Alaric and Attila. Fortunately for us now, it was the genius of free enterprise that created mass production and the same genius of American free enterprise that created mass production, and the same genius that invented it can and will excel in its use in the production of defense armament—given a fair chance."

Prentis singled out the conditions under which the National Defense Advisory Commission must function, since none of its members is its executive head. He recommended immediate selection of an executive head for this commission.

"So far as industry is concerned," he added, "what more can it do? It has cheerfully pledged and given its support to government. It has taken a definite stand against profiteering. It has supplied its best administrators. Despite the mouthings of demagogues, American industry could not be drafted. It had already volunteered.

"Today, with the defense emergency upon us, industry asks from government a fair deal instead of the shabby deal of recent years; faith instead of suspicion; active governmental sympathy and support instead of demagogic criticism; statesmanship instead of politics."

Next he urged business men to take stock of themselves, saying:

"Let us examine ourselves for a moment. Take our attitude as American citizens. How many of us have ever made a really serious effort to study and understand the philosophic and religious principles on which our system of government, of economies and of civil and religious liberties, is based? How many of you have ever read Thomas Hobbes' 'Leviathan,' John Locke's 'Essays on Government,' Montesquieu's 'Spirit of Law,' Milton's great essays on freedom of speech and freedom of the press, the Federalist Papers? Be honest now. How many of you have ever devoted even one full day of your time to governmental problems? How many of you have ever interested yourselves directly in politics—the devising of policies, the selection and election of good men to represent you in public affairs? How many of you, if called upon to mount a platform with Earl Browder, Norman Thomas or Henry

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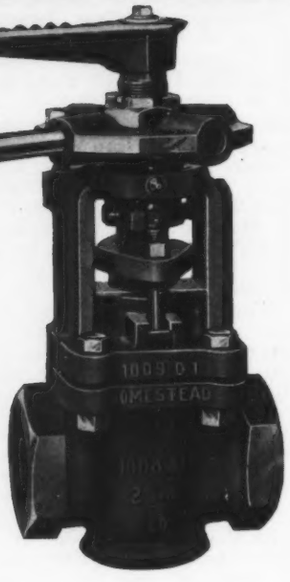

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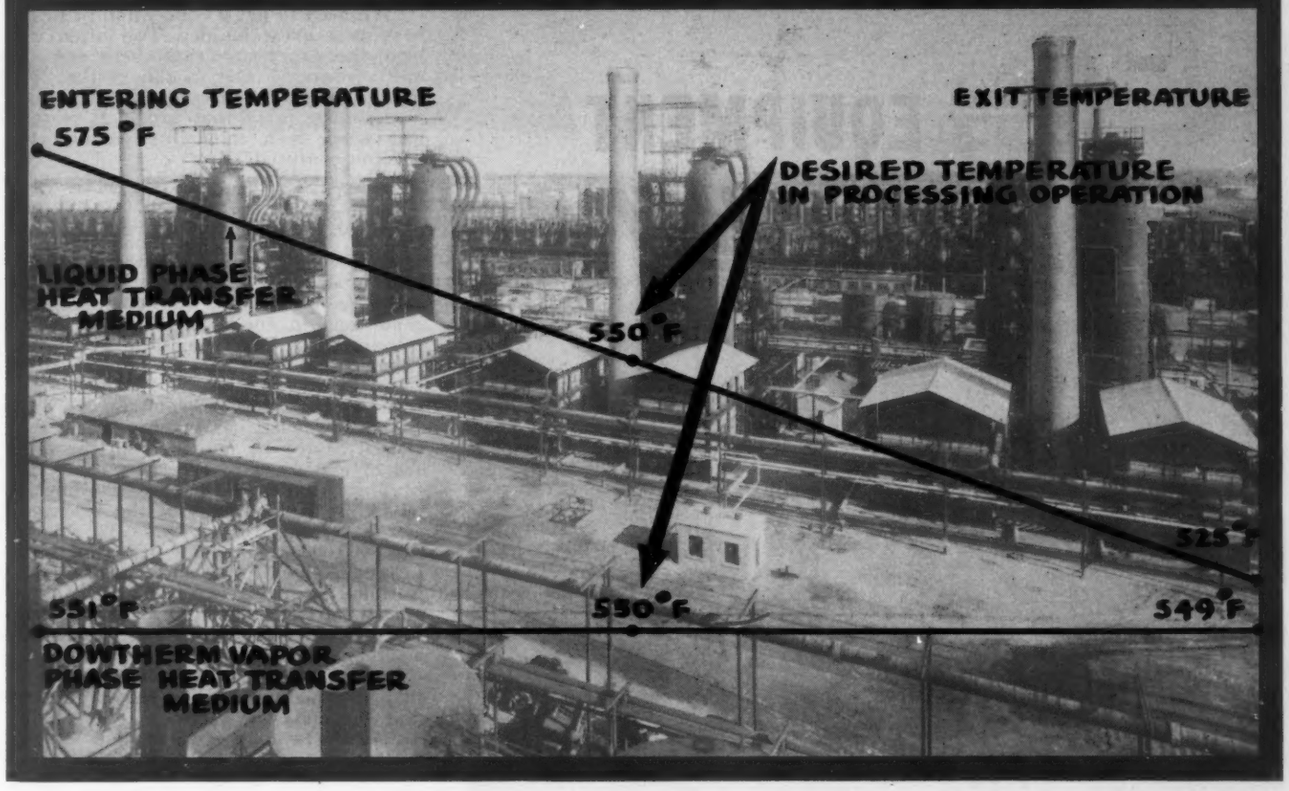

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Wallace, right now could offer even a sketchy explanation and defense of the principles on which the American republic is based?"

After listing both the men and means by which state socialism is being fostered by giving the impression that government can provide for individuals, Prentis mentioned a quotation from Owen Wister, which asked Theodore Roosevelt and Henry Cabot Lodge how long they expected the government at Washington to last, and got an answer of 50 years.

Prentis observed: "Forty-five of those fateful 50 years have elapsed. What do the next five hold? The answer will be found in how many real patriots are left among us; how many men who are willing, not only to give their lives if need be, but who will labor unceasingly and unselfishly with mind and heart and tongue to preserve our precious American heritage of freedom."

Cameron Blames Businessmen

Cameron placed the plight of business on businessmen themselves. His estimate of the situation is that men in business have learned too little from business.

"We were a pushover," he said, "when men began to blame business for its lack of contribution to American life. We did not know enough about what business has done and can do to counteract the appeal of the program the political reformers offered."

His remarks about the recent national election drew several rounds of laughter and applause. On the result of the election he said:

"But America got back her voice. Now we have a loyal opposition."

"You must remember," Cameron added, "that principles built on truth will be established. Whatever business has that is sound will prevail, and it will prevail without the benefit of any edict.

"Our job is to go on building the American economy, which has not been built. In this there is no room for defeatism. For instance, we hear men in business talk as if they believe there always will be unemployment. That is not the kind of America we want and it is not the kind of America business can build. It is the kind of attitude on which political planners thrive.

"We need to get a conception of business as a great builder. Too often we hear the expression that there are no more frontiers. The trouble is that we think of a frontier as something inviting. No frontier is of that order. It is too bad when men think just enough to become confused."

Dies on "Fifth Column"

Dies described activities of a "fifth column" in America, confining his proof to the record of the committee of which he is chairman.

Before going into his portrayal of conditions in the United States, Dies recounted the effectiveness of agents of German and Russian governments previous to invasion of the European nations which have been conquered.

To show what has taken place in the United States, he quoted from the record of exposures of the committee. He cited creation of the Worker's Alliance, following the congress of the Communist party in Moscow in 1937, which had 600,000 members; the American League Against War and Fascism, the National Negro Congress, and the Communist party organization in the United States, which he said has 20,000,000 members and an income of $10,000,000.

As remedies to prevent formation of such organizations, Dies recommended that business be active in teaching Americanism to its workers and to immigrants.

American Recycling Association Formed

As part of a short course program on condensate production and recovery at Kingsville, Texas, November 5 and 6, the American Recycling Association was formed. It was the decision of the group that a meeting be held each year and preliminary plans were made for provision of a short course of 12 weeks, which will be provided through the school of engineering of the Texas College of Arts and Industries, Kingsville.

Officials of the organization are: president, E. E. DeBack, Corpus Christi Corporation, Corpus Christi; vice president, O. L. Robert, Atlantic Refining Company, Philadelphia; secretary-treasurer, R. L. Peurifoy, director of engineering, Texas College of Arts and Industries, Kingsville.

Directors are: E. V. Foran, Foran, Knode, Boatright & Dixon, Houston; E. O. Bennett, Continental Oil Company, Ponca City; W. H. Vaughn, Tide Water Associated Oil Company, Palestine; Clyde Alexander, Corpus Christi Corporation, Corpus Christi; Henry N.

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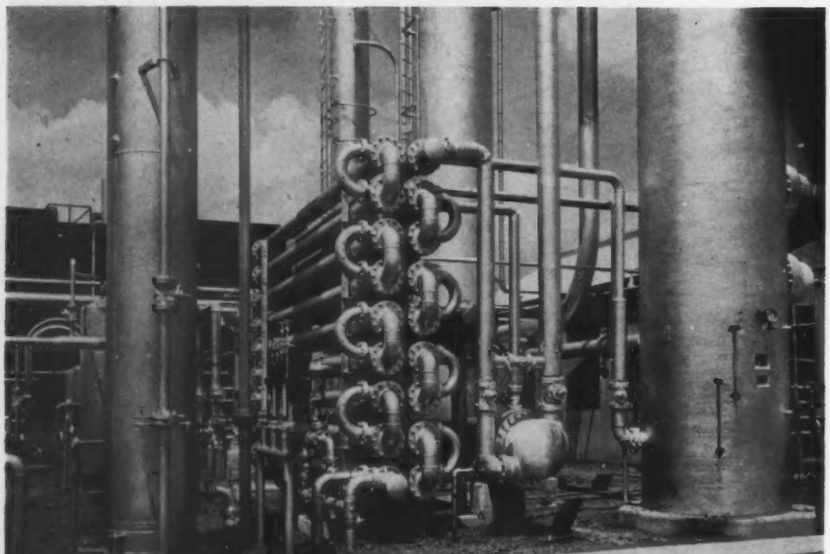

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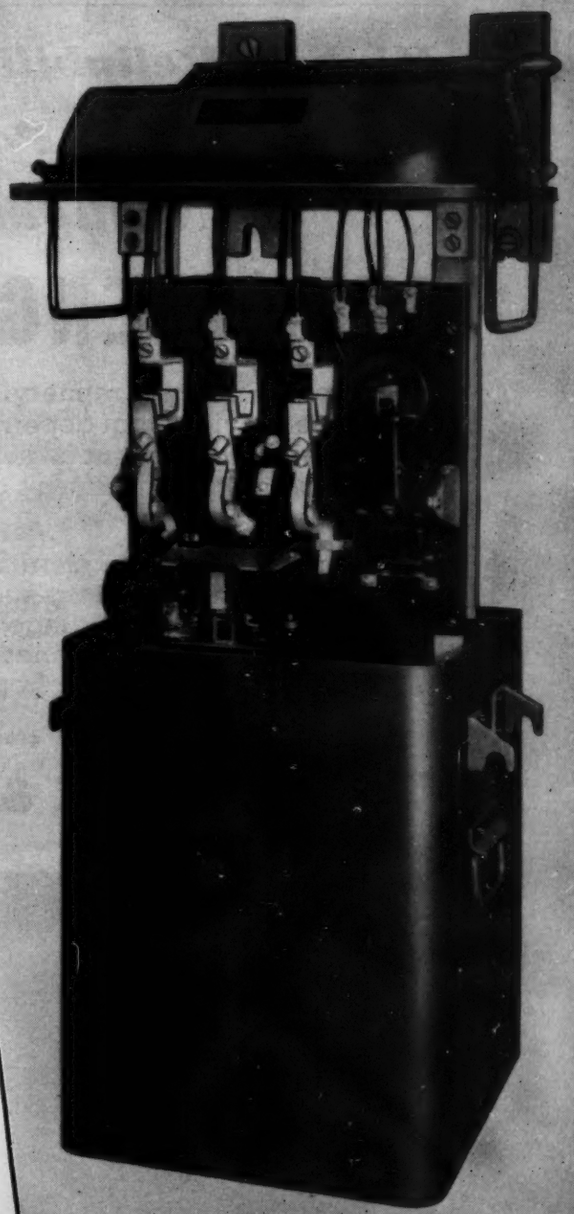

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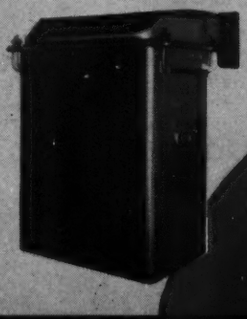

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A technical program of two days, an inspection trip of recycling plants and a banquet made up the program of the first meeting. A paper by Henry N. Wade, "Methods of Condensate Recovery," was read by E. E. DeBack. "Prediction of Sub-Surface Flows" was the topic of E. V. Foran. Dr. Monroe, Kreigel, Texas College of Arts and Industries, presented the paper of Dr. George Granger Brown on "Deviation of Natural Gas from Boyle's Law." Dr. F. H. Dotterweich, Texas College of Arts and Industries, and F. V. L. Patton presented, "Physical Properties of Hydrocarbon Mixtures in Condensate Production." Dr. Herbert Kaiser, of the Podbielniak Laboratories, Chicago, gave an illustrated discussion on "Operation of the Podbielniak Apparatus," while "Gas Hydrates" was the subject of Dr. O. L. Roberts, Atlantic Refining Company, Philadelphia.

Short Course Dates Set

Dates for the Southwestern Gas Measurement Short Course have been set for April 15-17, 1941. The program will be held at the College of Engineering, University of Oklahoma, Norman. The general committee met in Dallas, October 28, to consider preliminary arrangements.

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Coast Natural Gasoline Group Holds Fall Meet

The annual fall meeting of the California Natural Gasoline Association was held at the Ambassador Hotel, Los Angeles, November 1. Four papers were presented at morning and afternoon technical sessions, and the meeting concluded with the annual banquet and stag show in the evening.

R. E. Beckley acted as chairman of the opening morning session, and the first speaker was L. V. Cassaday, Lomita Gasoline Company, president of the association, who reviewed the accomplishments of the association during the first 15 years of its operation.

Following Beckley's address, M. W. Kibre, General Petroleum Corporation, delivered a report of activities carried out by 11 Technical Committees during the past year. Work of these committees in all lines of the industry's activities was reviewed. Reports were delivered by committee chairmen on bulletin reports. They included, "Physical Constants of the Components of Natural Gas and Gasoline," reported by D. A. Smith, Tide Water Associated Oil Company; "Low Temperature Fractional Analysis of Natural Gas and Gasoline," reported by Francis Laird, The Texas Company, and "The Chartman's Manual," reported by C. B. Heartwell, Standard Oil Company of California.

One technical paper was presented at the morning session, "Application of Mass Spectrometry to Analyses of Hydrocarbon Gas Mixtures," prepared by the research department, United Geophysical Company. Discussion leaders on this paper were F. N. Laird and Edward Shafer, Jr. This paper recorded the progress made in application of mass spectrometry to gas analyses. About two years ago the authors considered a number of problems arising in the qualitative and quantitative measurements of small quantities of hydrocarbons and attention was turned to the possibility of employing physical, instead of chemical, methods of obtaining the desired results. Investigation disclosed that the mass spectrometer presented the possibility of solving many problems not easily accomplished by other methods. The paper traced the development of this work, the necessary apparatus and the technique involved.

Opening the afternoon session, Henry N. Wade, Parkhill-Wade, presented a paper on "Distillate Recovery Systems." W. H. Geis, Union Oil Company of California, and Dr. W. N. Lacey, California Institute of Technology, were discussion leaders. Wade defined a "distillate-type structure" and discussed generally the retrograde phenomena. He commented on the various types of distillate plants, including simple separation at reduced pressure, separation after regenerative cooling, separation after refrigerated cooling, and absorption. The paper also included a description of field piping systems, gathering and return; two-sand completions; input wells; well patterns, and the patent situation. It was pointed out that it has not been very long since absorption plant operating pressures in California were around 35 pounds per square inch, and the pressures are now in the 400-450-pound range, and the trend is to even higher pressures. In the Mid-Continent, plants are operating at 1500

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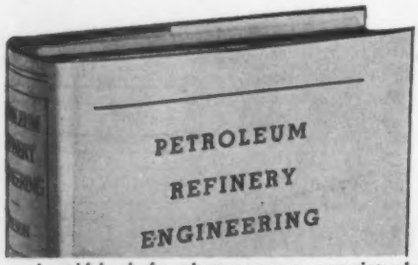

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pounds and even higher pressures, it was stated.

"Processes for the Conversion of Light Hydrocarbons to High Anti-Knock Aviation Fuels," was the second paper presented at the afternoon session by S. H. McAllister, Shell Development Company. Gale Adams, General Petroleum Corporation, and Charles A. Day, Jr., Richfield Oil Corporation, acted as discussion leaders. This paper reviewed present commercial methods for the production of high-octane fuels, including various polymerization processes and alkylation, both thermal and with sulphuric acid, as well as the latest processes such as hydrogenation and dehydrogenation. National defense aspects of this branch of the industry were also discussed by the author.

C. E. McCartney, Petrolane, Ltd., was the author of the final paper, "Commercial Butane, a Waste Material, Becomes a Valuable Product." Discussion leaders were S. F. Magor, The Superior Oil Company, and D. D. Purrington, Standard Oil Company of California. This paper presented a brief history of the expansion of the liquefied petroleum gas industry during the past 15 years, pointing out that commercial butane has a much greater economic value than the present market indicates and that it should be considered a product—not a waste material—and as such, it should carry its proportional share of plant overhead and plant operation costs. The paper advocated establishment of larger marketing differentials to warrant educational service and pioneering expenses. The use of commercial butane for alkylation and chemical processes was also discussed.

Regional Meeting In Shreveport

More than 100 persons attended the annual regional meeting of the Ark-La-Tex Division of the Western Petroleum Refiners Association at Shreveport, October 25. The program consisted of two technical papers:

"Refinery Waste, Method of Prevention and Control," by L. C. Burroughs, Shell Oil Company, New York, and

"Cupric Chloride Slurry Type Treatment of Cracked Distillates," by Robert G. Atkinson, Shamrock Oil & Gas Corporation, Amarillo.

R. T. Colquette, Root Petroleum Company, Shreveport, presided, and each paper was the basis for extended discussion.

Because the regional meeting came near the date for the November monthly meeting of the division, it was decided to have the next meeting, December 13, at El Dorado, Arkansas.

Texaco Refining Officials Promoted

With the promotion of C. E. Olmstead, who will now have charge of the export department of The Texas Company, Michael Halpern has been elected a vice president and given supervision of the refining department.

Olmstead will direct both export sales and production activities in foreign countries. He joined The Texas Company as an engineer in 1919, but resigned to become associated with California Petroleum Corporation in 1923. Purchase of this concern by The Texas Company

in 1928 brought his election as vice president of The Texas Company of California in charge of refining. Successively, he was vice president and general manager and president of the California subsidiary. Since 1938, he has been vice president of the parent company in charge of refining.

Halpern has been with The Texas Company since 1916. After serving at the Bayonne, Providence and Delaware River terminals, he became auditor of operations with headquarters at Houston. Next he was assistant superintendent at the Port Arthur works. He was transferred to New York as assistant manager of the refining department, and became general manager of refining in 1938.

Robinson Named President East Ohio Gas Company

J. French Robinson, who has been president of Peoples Natural Gas Company, Pittsburgh, has been elected president and a director of East Ohio Gas Company, Cleveland. He succeeds Charles E. Gallagher, who was elected chairman of the board.

J. F. Robinson

Robinson has been connected with gas and oil production and distribution since boyhood. He assisted his father in operation of a gas plant at Elizabeth, West Virginia, while attending high school. Later he attended West Virginia Preparatory School and West Virginia University, from which he was graduated in 1915 as a civil engineer.

Business connections with Baltimore and Ohio Railroad Company, Ford Run Franklin Coal & Coke Company and Seneca Hill Oil Company followed. He became assistant state geologist for Pennsylvania in 1922, and a year later joined Peoples Natural Gas Company as geologist and engineer. He was elected vice president in 1933, and president in 1936.

Edward M. Borger has been elected president of Peoples Natural Gas Company. His career since graduation from Duquesne University in 1922 has been spent with the concern. Since 1935, he has been general attorney and has held similar positions with Hope Natural Gas Company, New York State Natural Gas Corporation and other affiliated concerns.

Dr. W. B. Hendrey Joins Edwal Laboratories

Dr. W. B. Hendrey has joined the staff of Edwal Laboratories, 732 Federal Street, Chicago, as chief chemist. The laboratory manufactures special chemicals and has consultation service for industry and research.

Dr. Hendrey formerly was research and development chemist for The Texas Company. For six years he did grease and specialty research and for three years he was director of organic research. Recently he was assistant director of research for Spencer Kellogg & Sons.

November Demand Set Three Percent Below Year Ago

Current heavy stocks of gasoline and distillate fuel oil, unlikely to be reduced below last year's level even by conservative runs through the remainder of the year, influenced the United States Bureau of Mines on October 18 to make another reduction in its forecast of crude oil demand, seeing needed in November a daily average production of 3,570,000 barrels.

The November average is 10,600 barrels below the estimate for the current month, and 3 percent below the actual demand for November, 1939.

The bureau pointed out that daily average production during the four weeks from September 7 to October 5 was 3,639,000 barrels, while runs to stills were 3,604,000 barrels and domestic stocks decreased an average of 4000 barrels, indicating a demand of 3,643,000 barrels.

"The decline in production of Illinois crude is being offset in part by the liquidation of stocks of Illinois origin and by a seasonal decline in total national demand, so that the shift in the market demand for crude to other states has been less than anticipated," the bureau said.

"The high seasonal level of both gasoline and distillate fuel oil stocks indicates the possibility of lower runs during the winter months. The selection of heavier crudes, accompanied by moderate distillate yields and low gasoline

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yields, seems probable if the industry attempts to meet the strong demand for fuel oils.

"In appraising the position of gasoline stocks, even conservative runs during the last quarter of 1940 probably will not result in reducing stocks of finished and unfinished gasoline by December 31 below last year's level of 83,000,000 barrels. However, the increase in stocks of aviation gasoline represents an essential reserve for defense purposes and should be discounted in comparison to total stocks with previous years."

The bureau estimated that domestic demand for motor fuel in November will be 49,900,000 barrels, or 5.5 percent above the actual for that month last year.

One hundred thousand barrels was added to the October estimate for exports, the bureau explaining that although the forecasts by the principal shippers continued low in comparison with a year ago, a slight pick-up was indicated, but the 1,700,000 barrels earmarked for shipment abroad is 860,000 barrels under actual exports of November, 1939.

Stocks

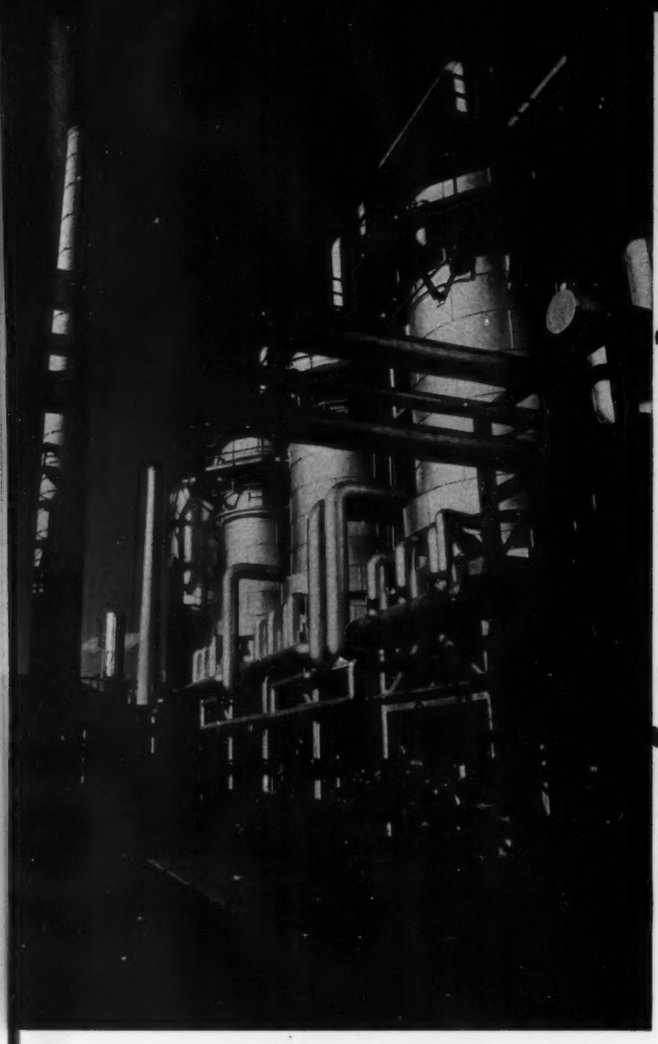
The report placed stocks of finished and unfinished gasoline on August 31 at 83,701,000 barrels, and cited current reports that about 3,000,000 barrels were withdrawn during September, leaving approximately 80,700,000 barrels at the close of that month, compared with 70,992,000 barrels on September 30, 1939. If both crude runs and the gasoline yield are kept relatively low, gasoline stocks will be further reduced in November by an estimated 900,000 barrels, it was said.

With benzol production and direct sales of natural gasoline estimated at 1,300,000 barrels, the indicated refinery production for the month was figured at 49,400,000 barrels, which the bureau distributed among the several refinery districts as follows: East Coast, 6,660,000 barrels; Appalachian, 1,820,000; Indiana-Illinois, 10,740,000; Oklahoma, 3,050,000; Kansas, 2,770,000; Inland Texas, 3,280,000; Gulf Coast Texas, 11,330,000; Gulf Coast Louisiana, 1,210,000; Inland Louisiana-Arkansas, 850,000; Rocky Mountain, 1,300,000, and California, 6,390,000 barrels.

The bureau estimated that natural gasoline to be blended at refineries will be 8.5 percent of the total refinery production, or 4,220,000 barrels. The yield

Bureau of Mines Forecast of Crude Oil Demand for November

State	Forecast Nov., 1940	Forecast Oct., 1940
Texas	1,291,000	1,320,000
California	583,000	583,200
Oklahoma	413,000	403,500
Illinois	385,000	405,200
Louisiana	274,000	274,200
Kansas	186,000	178,700
New Mexico	104,000	104,500
Wyoming	75,000	75,200
Arkansas	71,000	70,700
Michigan	51,000	53,900
Pennsylvania	45,100	45,100
Montana	18,900	17,700
Indiana	14,200	9,300
Mississippi	13,800	9,000
New York	12,500	12,000
Kentucky	12,300	12,200
West Virginia	8,500	9,100
Ohio	8,000	8,000
Colorado	3,700	3,900
	3,570,000	3,580,600



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of straight-run and cracked gasoline is estimated as 43.4 percent, the same as in October, which, applied to the production of 45,180,000 barrels, gives crude runs of 104,100,000 barrels, or 3,470,000 barrels a day.

Forecasts from exporters indicate that foreign shipments of crude "may hit a new low for recent years," but the bureau, nevertheless, retained the estimate of 3,900,000 barrels for next month. The estimate for crude to be used for fuel and losses has been reduced to 2,500,000 barrels.

On the basis of these factors, the bureau sees a total demand for domestic crude oil of 107,100,000 barrels in November, or 3,570,000 barrels daily, which it has allocated among the producing states, as shown in an accompanying table.

NPA Names Defense Group

In keeping with a resolution passed at the annual meeting in Atlantic City September 18, the National Petroleum Association has named the following defense committee:

N. H. Weber, The Pure Oil Company; C. L. Suhr, The Pennzoil Company; H. A. Logan, United Refining Company; Otto Koch, Kendall Refining Company; Fayette B. Dow, association counsel; Paul G. Blazer, Ashland Oil & Refining Company; W. H. Correa, Socony-Vacuum Oil Company; Peter H. Curry, South Penn Oil Refining Company; Clarence M. Davison, Standard Oil Company of New Jersey; C. E. Foster, Cities Service Oil Company; B. I. Graves, Tide Water Associated Oil Company; H. P. Hobart, Gulf Oil Corporation; W. T. Holliday, Standard Oil Company of Ohio; L. P. Lockridge, Sinclair Refining Company; Samuel Messer, Quaker State Oil Refining Corporation; R. G. Sonneborn, Franklin Creek Refining Company.

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National Council Announces 33 Safety Awards to Oil

There were 17 trophy awards within the petroleum industry as part of the 1939-1940 industrial safety contest, sponsored by the National Safety Council. In addition 16 certificates of merit were made within the petroleum industry. The announcement came during the annual meeting of the National Safety Council, October 7 to 11 in Chicago.

In the manufacturing division trophy awards went to:

Standard Oil Company of Louisiana, Baton Rouge plant, with 7,371,365 man hours and 6 injuries, and The Ohio Oil Company, Findlay, with 1,339,707 man hours and only 3 injuries.

In the natural-gasoline department trophy awards were to Shell Oil Company, Mid-Continent territory, with 335,645 man hours and no injuries; General Petroleum Corporation, Los Angeles, with 267,645 man hours and no injuries, and Hope Construction & Refining Company, Pittsburgh, 266,417 man hours and no injuries.

Certificates of merit in refineries were made to Standard Oil Company (Indiana), Chicago, for 12,445,593 man hours with 25 injuries; Humble Oil & Refining Company, Houston, 8,941,060 man hours and 24 injuries; Pan American Petroleum Corporation, New York, 400,023 man hours and 1 injury, and Indian Refining Company, Lawrenceville, 1,194,977 man hours and 3 injuries.

Safety Award to Leslie Cockrell

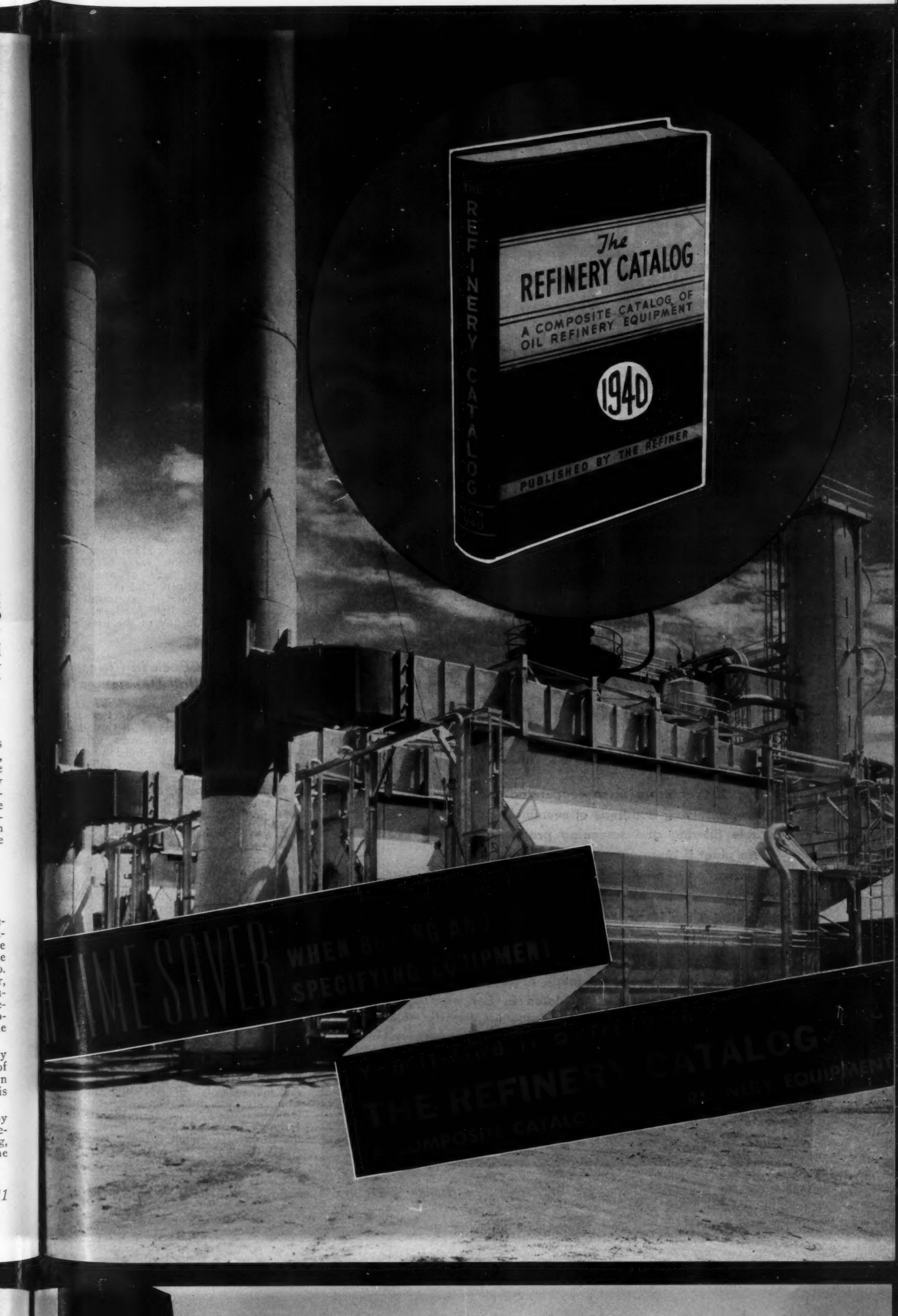
Leslie Cockrell, employe of The Texas Company at its Davenport, Oklahoma, natural gasoline plant, was awarded the president's medal of the National Safety Council, October 24. Cockrell by artificial resuscitation saved the life of Pete Sugovatty, 8 years old, who had swallowed gasoline. H. N. Pardee, division manager of the company, presented the award at Tulsa.

Egloff Awarded Chanute Medal

Dr. Gustav Egloff, director of research of Universal Oil Products Company, has been awarded the Octave Chanute medal for 1939-1940 by the Western Society of Engineers, Chicago. The medal was awarded for a paper, "Motor Fuels of the Present and Future," which Dr. Egloff presented December 7, 1939, and which was published in the April, 1940, issue of the journal of the society.

The medal was founded in 1902 by Octave Chanute, a former president of the society and one of the pioneers in the development of aviation through his work on gliders.

This medal is awarded annually by the society for the best papers on mechanical, civil and electrical engineering, presented before the society during the year, and published in the journal.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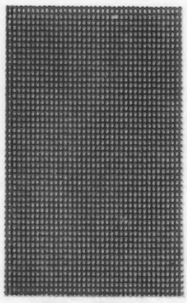

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Oil Industry Sets Fire Loss Record

The fire loss record for the petroleum industry reached its low point in 1939. The records have been kept for 10 years by the American Petroleum Institute, which gives this summary of the 1939 record:

Losses in all branches of the industry, based on reports covering 64,048 properties with an insurable value of about $1,000,000,000, averaged only 5 cents on every $100 of value, the lowest fire-loss ratio since 1930, according to D. V. Stroop, director of the Institute's Department of Engineering. In 1930 the fire-loss ratio averaged 14.9 cents per $100.

Total damage to structures, equipment, and contents other than oil stocks, amounted only to $491,900 last year, on properties with depreciated value of $978,738,167. The properties are representative of all branches of the industry, and include oil leases, tank farms, pipeline stations, natural-gasoline plants, refineries, bulk terminals, service stations, tank trucks, tankers and barges, and other properties. Fire-loss on oil stocks, reported separately, averaged 4.7 cents per $100 on oil stocks having a value of $383,974,763. This is less than the loss on other properties.

Best 1939 record was reported for the 402 tankers and barges covered. They suffered damage of only $1358 from fires on the total insurable value of $131,-902,586, a fire-loss ratio of one mill. Outstanding also were the records of refineries and inland bulk terminals, both of which had 1939 fire-loss averages lower than in any of the previous 10 years.

Ells Replaces Peck in Cities Service Gasoline Department

Harry A. Ells was appointed manager of the natural gasoline and chemicals divisions of Cities Service Oil Company November 1. He had been general superintendent of the division since January, 1937. The promotion followed the resignation of E. L. Peck.

Ells joined the Cities Service organization in 1923, following graduation from Leland Stanford University the previous year. After a period in construction work he went into the operations department of natural gasoline manufacture with the result that he went to headquarters in Bartlesville in 1926 as construction engineer for the division. Five years later he became operating superintendent and in 1937 he became general superintendent.

Universal Officials on Illinois Institute Board

Joseph G. Alther and John J. Mitchell, vice presidents of Universal Oil Products Company, have been elected trustees of Illinois Institute of Technology, the new Chicago school created by the merger of Armour Institute of Technology and Lewis Institute.

Alther, a native of Chicago and general manager of Universal Oil Products Company, was honored last February with an award of Modern Pioneer in Industry because of his development of the Universal Equiflux furnace. Mitchell was a member of the board of Armour Institute previous to the merger.

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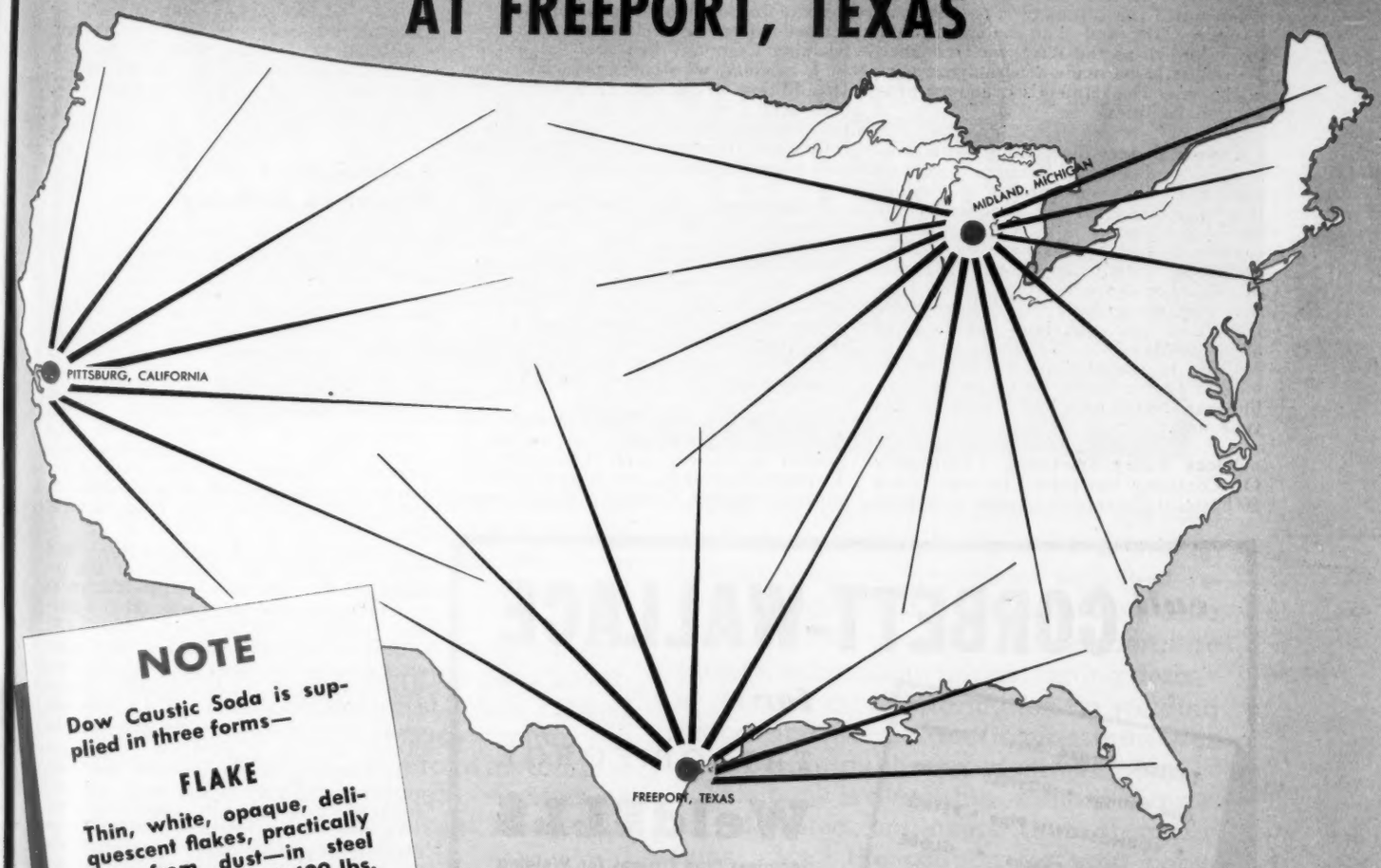

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▼ PLANT ACTIVITIES ▼

Texas Toluol Plant: The War Department announced last month that the $10,760,000 toluol plant for which it had contracted with Humble Oil & Refining Company, Houston, will be constructed and operated by the company on a cost-plus-fixed-fee basis, and title to the plant will remain with the government.

In its original announcement of the contract and an agreement under which the company was to install additional equipment to the amount of $1,097,000 in its present plant at Baytown, Texas, adjacent to which the new plant is to be erected, it was indicated that at the end of five years the company would have option of purchasing the property at cost less some pre-arranged rate of depreciation, or, alternative, at some negotiated sum.

The department's latest explanation indicates that the purchase option is given only with respect to the equipment which the company is to install in its own plant, and that the new plant, to be known as the Baytown Ordnance Works, is to be made a permanent part of the War Department's ordnance production facilities.

Canada Copper Sweetening: The Consumers' Co-operative Refiners, Ltd., has announced that subsequent to completion of a Universal Oil Products Company cracking unit at its Regina, Saskatchewan, refinery plans have been completed for installation of a 1500-barrel per day liquid-process type Perco copper sweetening unit. The unit will be completed and put into operation in about 60 days.

Prior to installation of cracking facilities, Turner Valley straight-run gasoline was treated by a Perco solid-process type unit.

Pecos Valley Skimming: Community Oil Company has placed in operation a 50-barrel daily capacity crude skimming plant in the Pecos Valley field, Pecos County, Texas.

Louisiana Recycling: Distillate Engineering & Processes Company has announced the sale of a license to The Texas Company under which that company will operate distillate or recycling plants.

The first plant will be located at Berwick, near Morgan City, Louisiana. Equipment is now being purchased for the project, which is scheduled for early completion. It is the second recycling plant under way for Louisiana. The first one is located in North Louisiana in the Cotton Valley field.

Cracking Unit: Mid-West Refineries, Inc., Grandville, Michigan, has contracted for a 2-coil Dubbs cracking unit from Universal Oil Products Company. Frick-Reid Supply Corporation has contract for the installation. The company was formed after two plants of Imperial Refining Company had been bought by B. J. Skinner, who has a plant at Alma. In addition to Skinner, president, officials are: T. E. McFall and V. M. Skinner, vice presidents; C. L. Fillmore, secretary and treasurer, and John Marshall, vice president and superintendent.

Pennsylvania Improvements: Wolverine-Empire Refining Company is undertaking improvements costing between $60,000 and $70,000 at its plant just outside Oil City, Pennsylvania. Improvements are being made to the retort department and filter house, and a new laboratory is being constructed to replace one destroyed by fire several months ago.

Douglas Cracking Plant: Douglas Oil & Refining Company has signed a license agreement with Universal Oil Products Company, and is now building in Los Angeles County a 2-coil selective Dubbs cracking unit with crude distillation equipment.

Universal Oil Products Company engineers designed the unit, including treating equipment and other auxiliaries, and Fluor Corporation, Los Angeles, is building it. Provision is made in the design for future increases in capacity, and for addition of a catalytic polymerization unit.

Officers of the company are: chairman of the board, Donald W. Douglas; president, George W. Stratton; vice president and director of operations and construction, William P. Andrews; secretary-treasurer, A. L. Bergere, and assistant secretary-treasurer, David C. Moore.

Washington Plant Increased: Montana Headlight refinery at Spokane, Washington, has been enlarged from 200- and 600-barrel capacity. The plant is taking production from Montana's Cut Bank field.

Wisconsin Plant Near Ready: Wisconsin Oil Refining Company's new plant at Sheboygan is near completion, scheduled to go on stream in late November. Capacity is 5000 barrels daily. President of the company is Dewey E. Foster.

Preliminary Census Report on Refining

The number of petroleum refineries in the United States increased from 365 in 1937 to 485 in 1939 or 32.9 percent, according to a preliminary report on the 1939 Census of Manufacturers made public by Director William Lane Austin of the Bureau of the Census.

These refineries produced gasoline, fuel oils, lubricating oils, illuminating oils and other products having a total value last year of $2,461,126,549. The report does not cover establishments primarily engaged in compounding refined or partially refined products, or those producing gasoline from natural gas.

Output increased between 1937 and 1939 for almost all products of the industry, but total value of production at the refineries last year was off 3.4 percent from the 1937 total of $2,546,745,730.

Cost of materials, supplies, fuel, purchased electric energy, and contract work was $1,933,264,243 in 1939, against $2,064,306,627, a drop of 6.3 percent, which more than compensated for the decline in value of products.

Refineries gave employment last year, on an average, to 72,840 wage earners engaged primarily in manufacturing. The final report will also include those performing distribution or construction work, providing a basis of comparison with 1937, when the total for all types was 83,182. The payroll for wage earners last year was $128,214,055. The same reservation must be made in drawing any comparisons with 1937, when the total was $140,414,750.

Salaried personnel, not including employees of central administrative offices, numbered 14,745 last year, or 3.4 percent less than the 1937 total of 15,268. Salaries, however, increased 5 percent from $36,393,120 to $38,194,786.

Gasoline, of course, was the biggest item produced, in terms of both quantity and value. Output last year amounted to 24,393,809,047 gallons, compared

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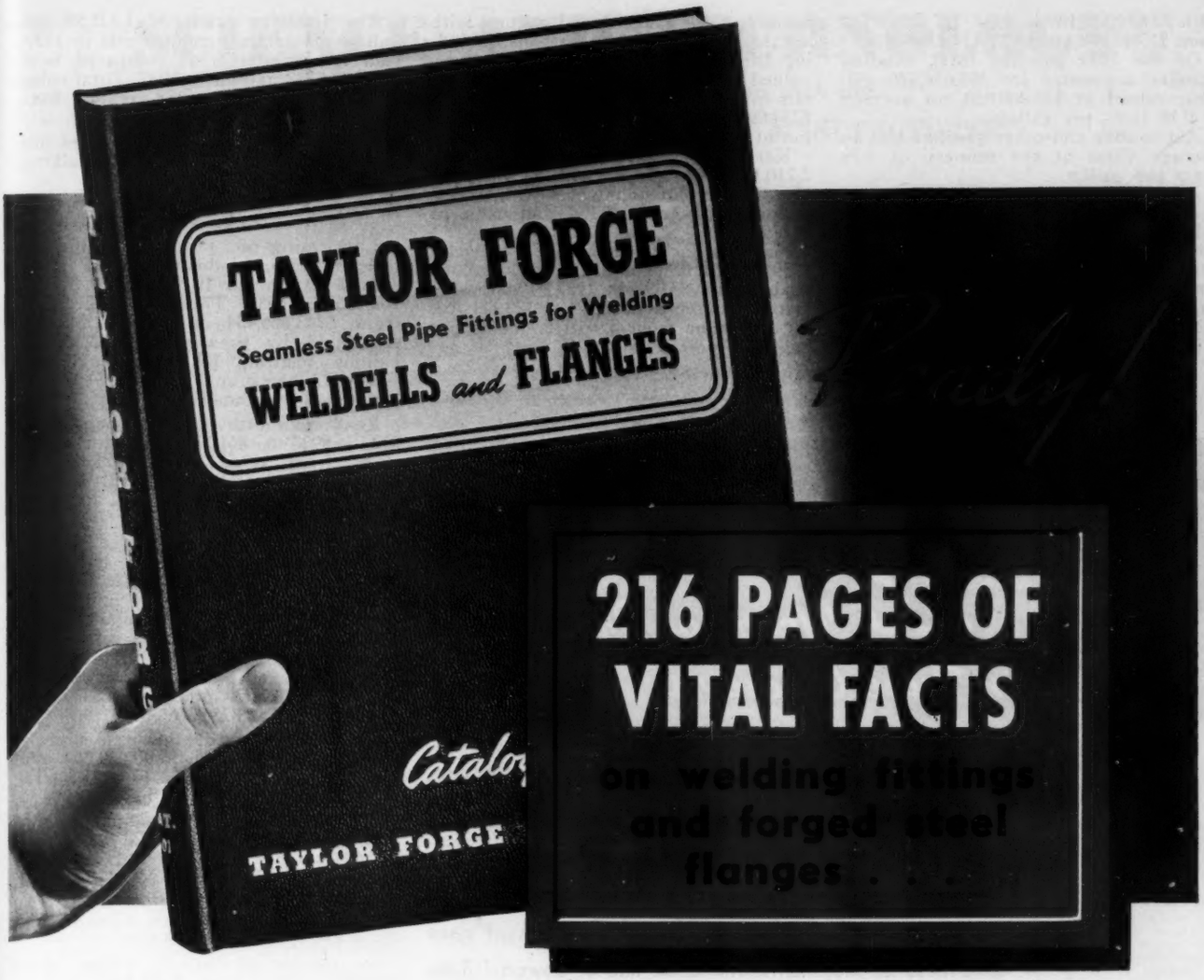

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with 22,626,325,189 in 1937. Its value fell from $1,447,688,118 to $1,424,436,179.

Of the 1939 gasoline total, aviation gasoline accounted for 395,654,926 gallons, valued at $36,268,950, an average of 9.18 cents per gallon.

Automobile and other gasoline had an average value at the refinery of 5.78 cents per gallon.

Fuel Oils

Fuel oils were the second most important type of refinery product. Last year's output amounted to 19,983,006,278 gallons, compared with 19,243,713,721 gallons in 1937. Value, however, fell from $512,904,099 to $472,209,414.

Of all fuel oils produced, distillates accounted for 2,866,729,603 gallons, with a value of $107,648,740; gas oils, including Diesel oils, for 3,972,609,427 gallons, valued at $130,467,274; and residual fuel oils for 13,143,667,248 gallons, valued at $234,093,400. The average value per gallon of residual fuel oil was 1.78 cents.

Kerosene production in 1939 totaled 2,710,108,704 gallons, with a value of $112,064,645. This compares with a 1937 gallonage of 2,508,045,150, and value of $123,681,070.

Naphtha, including benzine, reached a 1939 production of 392,771,685 gallons against 319,983,096 in 1937. Total value increased from $22,031,591 to $23,111,763, but a decline from 6.9 to 5.9 cents per gallon is indicated.

The industry produced 1,331,987,486 gallons of partially refined oils in 1939, sold for rerunning, as compared with 1,147,454,232 gallons in 1937. Total value was $38,878,489 last year, against $38,726,391 in 1937.

The bulk of the partially refined oils sold for rerunning, 1,013,264,715 gallons, was classified as above fuel oil.

Lubricants

Lubricating oils produced in the petroleum refining industry totaled 1,606,830,052 gallons in 1939, against 1,517,102,553 in 1937. Their value declined from $245,666,434 to $237,161,245. A separation by type shows 453,328,838 gallons neutral, 188,244,690 cylinder, 70,798,273 black, and 894,458,251 other, including compounded.

Road oils increased in gallonage from 592,556,892 to 861,772,078, with value rising from $19,521,797 to $25,680,795. Of the 1939 total, 608,914,551 gallons were liquid asphaltic road oils, and 252,857,527 gallons other types.

Gallonage of greases declined slightly from 61,925,798 to 61,884,768, but value rose from $17,215,900 to $17,323,676. The rise is accounted for by lubricating greases, which increased from 38,842,687 gallons to 43,009,529, and in value from $13,284,125 to $14,450,646. Petrolatum, mineral jelly, etc., declined from 23,083,111 to 18,875,239 gallons, and from $3,931,775 to $2,873,030.

Paraffin wax production rose slightly from 90,608,190 gallons to 90,649,364, and in value from $19,213,203 to $19,484,714.

Acid oil gallonage in 1939 was 55,272,890, valued at $784,433, compared with 57,633,349 gallons valued at $1,015,991 in 1937.

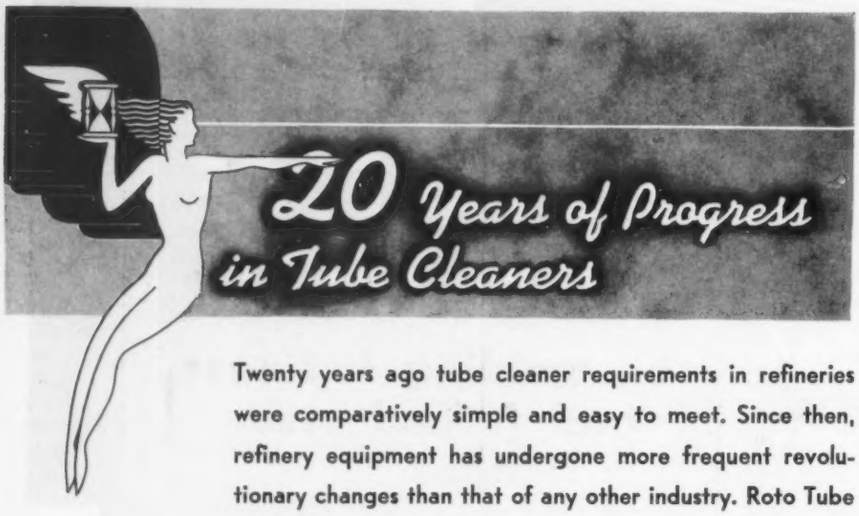
Liquefied petroleum gases show a gain from 101,075,825 gallons in 1937 to 133,297,473 in 1939, with value rising from $3,355,409 to $4,495,670.

Production of asphalt (other than liquid) shaded from 2,971,038 tons to 2,344,595, with a drop in value from $31,352,147 to $20,852,435.

Petroleum coke production rose from 1,327,238 tons to 1,521,740, but value fell from $5,048,049 to $4,987,247.

Other refinery products increased in value from $48,787,183 to $51,460,615.

The report on petroleum refining was prepared under the direction of Thomas J. Fitzgerald, Chief Statistician of the Division of Manufactures.



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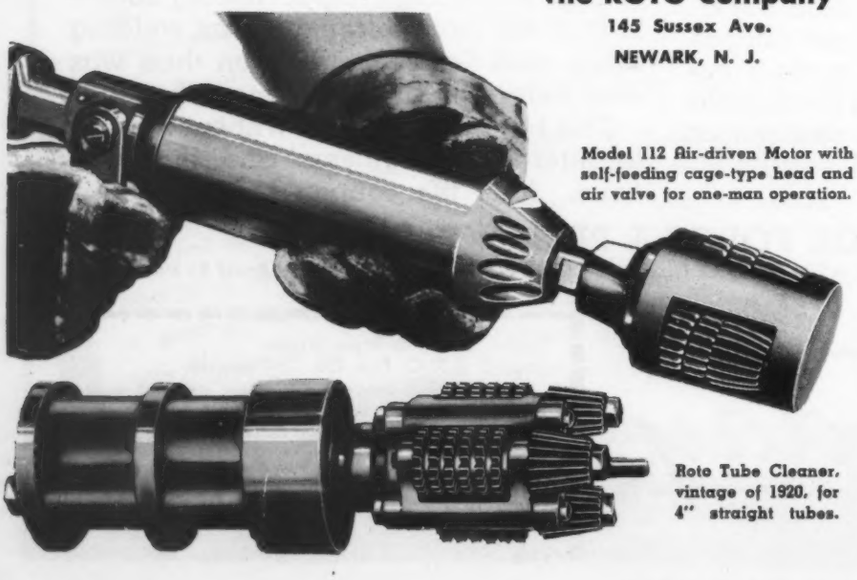

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F. S. Shepard, manager of refineries for Socony-Vacuum Oil Company in the eastern area, died October 10 in New Rochelle, New York. He had been with the organization since graduation from Harvard University in 1903.

J. S. Cosden Dies Suddenly

J. S. Cosden, president of Cosden Oil Company, Fort Worth, died suddenly November 17 on a train at Willcox, Arizona. He was traveling from California to Florida. Cosden was one of the colorful figures of the oil industry and founder of what is now the Mid-Continent Petroleum Corporation.

SCIENCE AND TECHNOLOGY

Abstracts prepared in co-operation with the

REFINER AND NATURAL GASOLINE MANUFACTURER

by

THE LESLIE LABORATORIES

Traver Road, Ann Arbor, Mich.

under the supervision of

DR. E. H. LESLIE and DR. H. B. COATS

The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical and Chemical Data

Phase Equilibria in Hydrocarbon Systems, B. H. SAGE, R. A. BUDENHOLZER, AND W. N. LACEY, *Ind. & Eng. Chem.* **32** (1940) pp. 1262-77.

Experimental data with regard to the volumetric behavior of binary hydrocarbon systems in the liquid or gaseous regions are few. Such as exist are briefly reviewed. In the investigation reported in the paper the specific volume of each of twenty-four mixtures of methane and n-butane was determined as a function of pressure and temperature at pressures as high as 3500 pounds per square inch throughout the temperature interval between 70° and 250° F. These experimental results were interpolated to even values of pressure and composition and are presented in tabular form. Derived values of the isothermal enthalpy-pressure coefficient for several of the mixtures are recorded. From these primary data the partial volumetric behaviors of methane and n-butane were calculated throughout the single-phase region at seven temperatures between 70° and 250° F. The partial enthalpy and the fugacity of these components were computed as functions of state for the greater part of the gaseous region. The partial thermodynamic behavior of each component is recorded in tabular form. Diagrams illustrating the behavior of this binary system are included.

P-V-T Relations of Propylene, W. E. VAUGHAN AND N. R. GRAVES, *Ind. & Eng. Chem.* **32** (1940) pp. 1252-6.

The P-V-T relations of propylene have been measured over the pressure range 2 to 80 atmospheres and at temperatures varying from 0° to 300° C. the critical constants are as follows: t_c, 91.4° C.; P_c, 45.4 atmospheres; V_c, 180 cc. per mole; d_c, 0.233 gram per cc. Except for a few scattered and often unreliable values on critical constants of some of its homologs, ethylene is the only olefin for which a reasonably complete set of P-V-T data exists. The rapidly increasing use of olefins as starting materials for many important products requires more exact knowledge of the physical behavior of these compounds. The apparatus and procedure used in the work is described in some detail. Data are presented in tabular and graphical form.

Nomograph for the Clausius-Clapeyron Equation, C. L. CRAWFORD, *Ind. & Eng. Chem.* **32** (1940) p. 1280.

Because of the limited range of many vapor pressure data, various methods have been devised for the interpolation and extrapolation of existing data on straight-line graphs—e.g., the Cox chart, Duhring rule, and the plot of log P vs. 1/T, where T is the absolute temperature at which a substance has the vapor pressure, P. A nomograph for the Clausius-Clapeyron equation is presented that eliminates the calculation of the points and/or the slope, the points being plotted directly in mm. and ° C., and the molar latent heat being plotted on or read from its line. It is noted that the chart can be no more accurate than the error-producing assumptions made in the derivation of the Clausius-Clapeyron equation. These assumptions are: that the latent heat of vaporization of any substance is constant; that the volume of the liquid is negligible in comparison with that of the vapor, and, that the perfect gas law holds. The chart must thus be used judiciously, and if so used will be found convenient.

The Calculation of the Compositions of Phases in Equilibrium, G. SCATCHARD, *Jour. Am. Chem. Soc.* **62** (1940) pp. 2426-9.

The compositions of two phases of a binary system that are in equilibrium may be conveniently determined by plotting for each phase the activity, or the chemical potential, of one component against the same property of the other component, with the same standard for each state of aggregation. At equilibrium the two curves intersect. The corresponding compositions can be determined from an auxiliary plot either of activity or chemical potential against composition. The application of this method to several typical systems is illustrated.

Chemical Composition And Reactions

Preparation and Some Physical Properties of 2,2,4,4-Tetramethylpentane, F. L. HOWARD, *J. Res. Natl. Bur. Stand.* **24** (1940) pp. 677-84.

The preparation of a zinc-copper couple is described, and the preparation of $ZnMe_2$ from this couple and methyl iodide is given. $ZnMe_2$ was cooled below 7° C. and 1500 cc. of tetralin and 1190 grams of 2,2,4-trimethyl-4-chloropentane were added during 6 to 8 hours time. After standing overnight water was added, followed by 15% HCl. The organic layer was washed with water, 5% sodium carbonate, water, and dried over calcium chloride and distilled, yielding 595-cc. of crude 2,2,4,4-tetramethylpentane. Purification of this material is described. On distillation it yielded a hydrocarbon having a boiling point of 122-3° C., freezing point of —66.6°, and other physical properties that are tabulated.

Researches on Asphaltenes, Part I, F. J. NELLENSTEYN AND J. P. KUIPERS, *Jour. Inst. Petr.* **26** (1940) pp. 401-6.

The difference in solubility of asphaltic bitumen in solvents having the same surface tension, such as ether and petroleum spirit, is explained. The solubility of asphaltic bitumen from Trinidad-Lake asphalt and the separation of light-colored compounds in the ether extract of this bitumen prove that incomplete miscibility of the oily medium and the protective substances of the asphaltic bitumens with petroleum spirit enters into action. The ether-soluble, petroleum-spirit-insoluble compounds appear to be present in almost all asphaltic bitumens. Their role in the asphaltic bitumen system has not been determined; they should probably be considered as belonging partly to the oily me-

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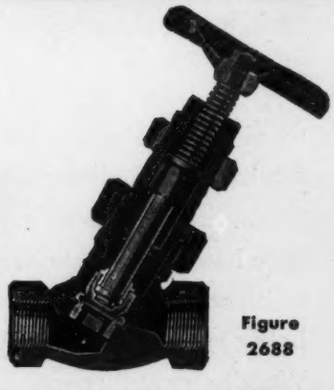

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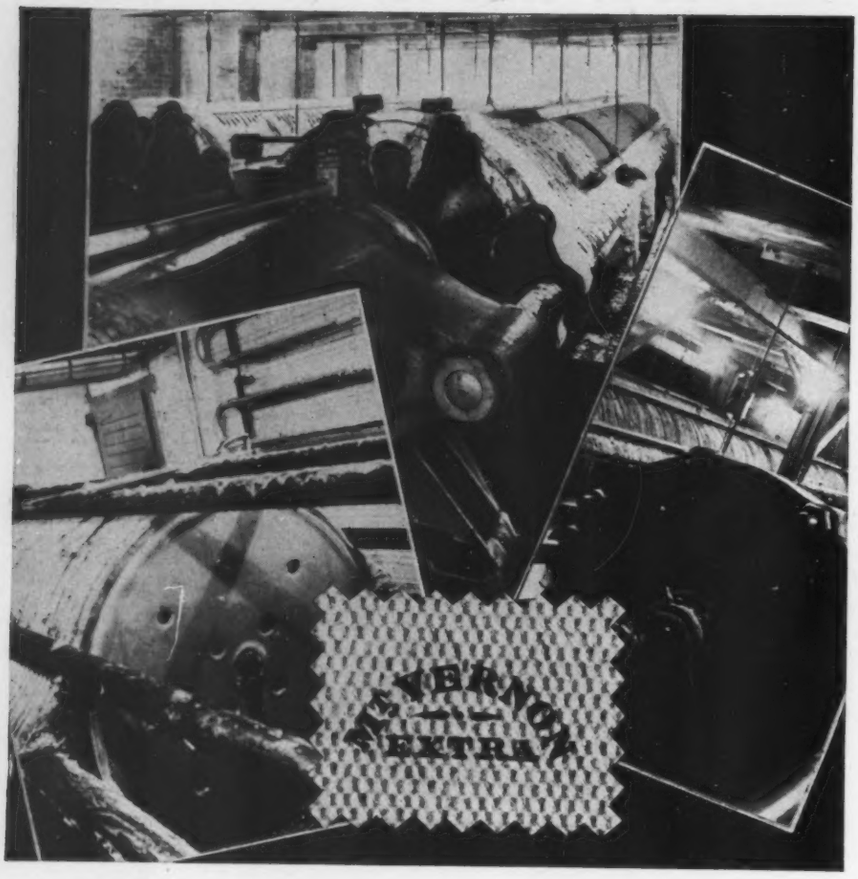

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dium, and partly to the protective bodies. Ethyl ether should be preferred to normal gasoline for the asphaltene determination. The practical advantages of ether for the determination of asphaltenes have already been given. It appears, however, that also from a theoretical standpoint ether should be used instead of the usually employed normal gasoline. The ether asphaltenes in most instances are pure flocculates, while the petroleum-spirit precipitates of asphaltic bitumen are mixtures of a flocculate with a demixing precipitate. The presence of highly oxygenated substances in Trinidad-Lake asphalt can be proved by extraction of the difference-asphaltenes with acetone.

Notes on the Preparation and Properties of Some Aliphatic Hydrocarbons, L. SCHMERLING, B. S. FRIEDMAN AND V. N. IPATIEFF, *Jour. Am. Chem. Soc.* **62** (1940) pp. 2446-9.

The syntheses of three hexanes, one heptane and three octanes are described. These include 2-methylpentane, 2,2-dimethylbutane, 2,3-dimethylbutane, 2,2,3-trimethylbutane, 3,4-dimethylhexane, 2,2,3-trimethylpentane, 2,3,4-trimethylpentane. The boiling points, refractive indices, densities, and octane numbers of these hydrocarbons are given. The properties of some of the intermediate compounds prepared in the course of the syntheses of the hydrocarbons are also given.

The Partial Reduction of Acetylenes to Olefins Using an Iron Catalyst, A. F. THOMPSON, JR., AND S. B. WYATT, *Jour. Am. Chem. Soc.* **62** (1940) pp. 2555-6.

The problem of the reduction of the acetylenic compounds to the corresponding olefins has engaged the attention of many workers. Previous investigations of catalysts for this purpose are briefly reviewed. The announcement by Paul and Hilly of an iron catalyst unable to effect the reduction of olefins is regarded as of considerable importance, and it was decided to investigate the properties of this catalyst. The results are given for the reduction of three acetylenic compounds, and the authors conclude that the usefulness of an iron catalyst in the reduction of acetylenes to olefins has been demonstrated. Such reductions can be effected, even in the presence of a conjugated system of carbon-carbon double bonds without having to stop the reduction.

The Classification of Oil Shales and Cannel Coals, A. L. DOWN AND G. W. HIMUS, *Jour. Inst. Petr.* **26** (1940) pp. 329-48.

Attention is directed to the confusion that exists in the nomenclature and classification of naturally occurring oil-yielding materials. A system of nomenclature based on the principal plant and mineral components and a classification showing the inter-relationships and gradation of properties of these substances is suggested. Class I contains the oil sands, tar sands, and bituminous limestones; Class II contains the Kerogen rocks and oil shales; Class III contains the coals of the peat → anthracite series. The paper is largely confined to a consideration of Classes II and III. The article is illustrated with a number of excellent photomicrographs, and concludes with a detailed tabular classification.

Manufacture: Processes and Plant

Multicomponent Rectification, E. R. GILLILAND, *Ind. & Eng. Chem.* **32** (1940) pp. 1220-3.

A graphical method for estimating the number of theoretical plates required for a given separation as a function of the reflux ratio is presented. It is necessary to know the values of the limiting conditions, i.e., minimum number of plates at total reflux and minimum reflux ratio with infinite number of plates. It is not suggested that the method replace more accurate procedures, but that it be used for making preliminary surveys and for orienting the designer before he makes his detailed calculations.

Corrosion, Heat, Abrasion-Resistant Materials for the Construction of Chemical Engineering Equipment, *Chem. & Met. Report,* **47** (1940) pp. 597-612.

Prior to the introduction of stainless steels shortly after World War I, corrosion had been accepted as an evil about which little could be done. Development of the stainless steels has made available a new group of materials that experience has shown to be of tremendous importance from the standpoint of corrosion resistance and also in many other directions. Numerous other construction materials and procedures have been greatly improved during the same period. At the same time, new materials have been developed, such as impervious carbon and graphite, synthetic resins, and rubber-like products. The report of the editors of Chemical and Metallurgical Engineering

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serves to bring engineers up to date on the progress that has been made in recent years in the field of construction materials. Properties of the ferrous and non-ferrous alloys are presented on an accompanying large wall chart. For each material is given the manufacturer's name and address, the physical and mechanical properties, resistance to corrosion by commonly-encountered chemicals. Comparative prices of the stainless steels are given. Non-metallic materials are grouped according to types; each is accompanied by the manufacturer's name and address, the physical and mechanical properties, and in some instances by corrosion-resistance data.

Economic Pipe Size, B. R. SARCHET AND A. P. COLBURN, *Ind. & Eng. Chem.* **32** (1940) pp. 1249-52.

One of the major problems encountered in the process industries is the continuous transportation of gases and liquids of various viscosities. Consideration of the large investment often involved in piping systems indicates the wisdom of choosing sizes of pipes for the greatest economy. The economic pipe size, for which the sum of pipe and pumping costs is a minimum, has been derived both for the turbulent and viscous regions of flow. The resulting equations are represented by convenient nomographs. By solving the optimum-diameter equations simultaneously with the critical Reynolds number, a convenient relation has been found to indicate whether any given flow will be turbulent or viscous in a pipe of optimum diameter. Although the optimum velocity of many liquids in turbulent flow runs from 3 to 4 feet per second, much lower optimum velocities are calculated for very viscous liquids.

Soil Mechanics in Foundation Engineering, R. L. JAMES, *Jour. Inst. Petr.* **26** (1940) pp. 365-74.

It is only during comparatively recent years that soil has received much attention as an engineering material. The names of those who have made important contributions to the subject are mentioned. Subjects of soil behavior, influence of grain shape, influence of grain size, capillary forces, shrinkage, swelling and friction are discussed. The subject of foundations is then considered, and it is noted that probably 70 percent of the engineering failures are caused by faulty foundations. It is not correct to imagine that because 2 tons can be carried on 1 square foot, it is only necessary to construct a rigid footing slab of 100 square feet area to carry 200 tons. The subject is much more complex than this. Diagrams are presented showing the distribution of stresses below a foundation, and the ratio of stresses to settlement.

How Process Industries Are Meeting Their Water Supply Problems, G. L. MONTGOMERY, *Chem. & Met. Engr.* **47** (1940) pp. 622-5.

Necessity for the relocation of industries and the expansion of existing plants as part of the defense program are only part of the reason why chemical process industries are looking more closely than ever before at problems relating to water supply. New supplies in sufficient quantity and of good quality must be found in many cases. In other instances increased cost of water following a period of receding levels must be offset by greater efficiency in water pumping. A map is presented showing the hardness of the water, characteristic of different parts of the country. A second map shows the trend of water levels in recent years in different parts of the country. A third map shows the concentration of process industry requirements for water in different parts of the country.

Hydrogenation of Petroleum, E. V. MURPHREE, C. L. BROWN, AND E. J. GOHR, *Ind. & Eng. Chem.* **32** (1940) pp. 1203-12.

From the time of Satatier until the middle of the third decade of this century, commercial hydrogenation was practiced to a limited extent under restricted conditions. Effective catalysts, composed mainly of reduced nickel, were available, but impurities in the feed or hydrogen, such as sulfur or arsenic, de-activated these catalysts rapidly. Since coal and oil contain these catalyst poisons, the limitations made it impossible to hydrogenate carbonaceous materials of mineral origin. Hydrogenation was therefore limited to the treatment of fats and oils of animal and vegetable origin. The discovery, however, of sulfur-resistant catalysts, made possible the hydrogenation of mineral materials, although the use of pressures of 3000 to 4000 pounds per square inch was required. As a result of the work done, hydrogenation has been adapted to many applications, including: high-octane-number aviation gasoline produced from kerosene and gas oil fractions; motor gasoline production from gas oils; aviation blending agent production by saturation of branched-chain polymers; production of high-grade Diesel fuels from low-quality gas oils; production of water-white paraffinic kerosenes from inferior-quality distillates; production of high-viscosity-index lubricating oils from poor quality lubricating distillates; refining of gasolines to low sulfur content and high

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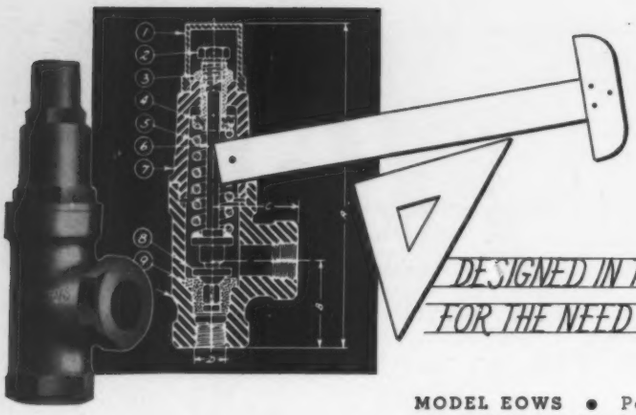

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stability; conversion of asphaltic crudes and refinery residues into lower boiling gas oils of increased paraffinicity; preparation of low-aniline-point high-solvency naphthas; preparation of high-flash high-octane-number safety fuels. The theoretical background of these several adaptations is discussed briefly, and the commercial applications of the more important of them are presented in some detail. At the present time commercial hydrogenation for the making of lubricating oils from solvents and paraffins has been superseded by solvent extraction methods. The article is well illustrated, and contains many data, and is concluded with a bibliography of thirteen references.

A Review of the Aliphatic Organic Chemical Industry, H. F. ROBERTSON, *Chem. & Ind.* **59** (1940) pp. 603-7.

On account of the breadth of the subject the paper is limited to a discussion of the products derived from the lower olefins, ethylene and propylene. Among the products considered are methanol, ethanol, acetone, acetic anhydride, ethylene glycol, diethylene glycol, propylene glycol, dipropylene glycol, triethylene glycol, tetraethylene glycol, hexaethylene glycol, 1,3 butylene glycol, ether and ether esters, such as methyl, ethyl, and butyl ethers of ethylene, and diethylene glycol, octyl alcohol, methyl amyl carbinol, 2, ethyl-butyl-alcohol, normal hexanol, methyl isobutyl ketone, carbitol, methyl ethyl ketone, diisobutyl ketone, diacetone alcohol, isophorone, dehydracetic acid, or dehydranone, several aldehydes, tetra-ethyl-ortho-silicate, triethanolamine, ethylene diamine, diethylene triamine, tetraethylene pentamine, pentaethylene tetramine, isopropanolamine, morpholine, tergitols, and carbowax. The uses of each of these compounds, as well as some related compounds, are briefly discussed. The article is an excellent informative review of this general subject.

Synthetic Rubber, E. V. MURPHREE, *Ind. & Eng. Chem.* **32** (1940) p. 1157.

The synthetic rubbers that are being produced commercially or have been announced as approaching the state of commercial production are: neoprene, Buna-S, Perbunan, Ameripol, and Butyl rubber. All of these have applications for specialty purposes. However, the major interest in synthetic rubber from the standpoint of national defense is in its application in the making of tires. Buna-S is a copolymer of butadiene and styrene. Perbunan is a copolymer of butadiene and acrylic nitrile. Neoprene is an acetylene polymer containing chlorine. A new type of synthetic rubber recently announced is Butyl rubber. The production cost of rubber of the synthetic type based on acetylene or butadiene appears to be substantially higher, even when on a large scale, than the cost of producing and delivering natural rubber, which has been estimated to be 7 to 8 cents per pound. Butyl rubber, since it is produced more directly from petroleum than the raw materials for the other types of rubber, may be somewhat cheaper, both in production cost and from the standpoint of plant investment.

Studies on the Separation of Paraffin Waxes. Part I. Principles Involved in the Fractional Melting of Wax, M. F. SAWYER, T. G. HUNTER, AND A. W. NASH, *Jour. Inst. Petr.* **26** (1940) pp. 390-400.

The waxes used in this investigation had components melting within the range 105-142° F., and assuming that the components are n-paraffins, the waxes might have contained hydrocarbons from $C_{23}H_{44}$ to $C_{28}H_{58}$. The paper is largely concerned with a discussion of the choice of a physical property to characterize wax. A typical equilibrium diagram for component forming solid solutions is presented and explained. The problem of the selection of a physical property for the characterization of the wax phases is then considered. Among the properties discussed are: molecular weight, refractive index, specific gravity, aniline point, and melting point. It was concluded that melting point is the most suitable physical property for the characterization of waxes, since it can be determined without difficulty to ± 0.05° F. by using a simple apparatus, and also, although it does not strictly follow the mixture law, there is not a great difference between the experimental values and those values calculated on the assumption that the mixture law is followed. The relationship between molecular weight and melting point for the n-paraffins can be expressed by the equation $T = \frac{414.5\,M}{M + 94.4}$, in which T is the melting point in °K. of the n-paraffin of molecular weight M.

The Manufacture and Testing of Roofing-Felts and Damp-Courses, D. M. WILSON, *Jour. Inst. Petr.* **26** (1940) pp. 377-89.

The history of the development of roofing-felt is briefly considered. Bituminous roofing-felts comprise a fibre base coated on one or both sides with bitumen. The saturant is usu-

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ally an asphaltic bitumen of the straight-run type having a penetration at 25° C. of between 100 and 200. A coating of asphaltic bitumen is applied to one or to both sides of the already saturated fibre sheet. It acts as a seal and fills any voids that may remain after saturation. The coating is commonly a blown bitumen. A high melting point is necessary to withstand exposure to high sun temperatures. However, it must also remain pliable over a wide range of temperature. The characteristics of suitable bitumens are given. The blowing of bitumens to be used as coating stock is discussed.

Products: Properties And Utilization

The Use of Bitumen Emulsion in Soil Stabilization, A. E. LAWRENCE, *Jour. Inst. Petr.* **26** (1940) pp. 357-64.

The subject of soil stabilization is briefly reviewed. The nature and composition of soils is considered, and a basis of classification is given. Soils can be stabilized by the addition of bituminous emulsions. Sufficient emulsion is not added to waterproof the soil, but only to increase the resistance to capillary water sufficiently to result in stabilization.

Spiral Screen Packing for Efficient Laboratory Fractionating Columns, H. S. LECKY AND R. H. EWELL, *Ind. & Eng. Chem., Anal. Ed.* **12** (1940) pp. 544-7.

A column packing suitable for laboratory fractionating columns is described. The packing comprises a continuous flat spiral of metal gauze enclosed between two concentric glass tubes. The steps in the development of this type of packing are briefly reviewed. Data and curves are given showing the efficiency of this type of packing. A cupped type of spiral packing gave approximately 18 theoretical plates per foot of height, although another form of the spiral packing somewhat more difficult to make gave as many as 32 theoretical plates per foot of height.

Saybolt One Fifteen Viscometer E. W. DEAN, E. L. RUH, AND R. W. WALKER, *Ind. & Eng. Chem., Anal. Ed.* **12** (1940) pp. 540-2.

Modern developments in the production and utilization of lubricating oils have created a need for a higher degree of precision in the determination of viscosity than can be attained by use of the Saybolt Universal viscometer. The Saybolt One Fifteen viscometer, which is described in detail in the article, is identical with the Universal instrument except that the diameter of the outflow tube is smaller. This increases the efflux time and accomplishes the double purpose of improving the accuracy of determinations in the low range and reducing the ratio between differences in terms of the Saybolt outflow time and kinematic viscosity. A table is given showing the Saybolt Universal viscosity, the kinematic viscosity, the Saybolt One Fifteen actual viscosity, and the Saybolt One Fifteen calculated viscosity. Equations are given for the conversion of viscosities, as well as a working table for these conversions.

Apparatus for Semimicrodetermination of Carbon and Hydrogen, C. NIEMANN AND V. DANFORD, *Ind. & Eng. Chem., Anal. Ed.* **12** (1940) pp. 563-6.

The authors describe in considerable detail the construction and operation of an apparatus specifically designed for the semimicrodetermination of carbon and hydrogen in all types of organic compounds. The furnace combustion train and auxiliary equipment are included in this description. A table is given showing the results of typical analyses performed by students who had less than sixty hours experience in quantitative determination of carbon and hydrogen in organic compounds. The agreement between the calculated and determined values for carbon and hydrogen is surprisingly good.

Determination of Sulfide Sulfur in Alkaline Solutions Containing Other Sulfur Compounds, J. B. LEWIS, *Ind. & Eng. Chem., Anal. Ed.* **12** (1940) p. 535.

The author calls attention to the fact that in the determination of sulfide sulfur in alkaline solutions containing other sulfur compounds it is essential that the solution be kept alkaline at all times. The minimum alkalinity required is 2% in terms of sodium hydroxide. If such alkalinity is not maintained the lead sulfite will precipitate, since it has been found that lead sulfite is not soluble in either cold or warm ammonium acetate solution even in the presence of acetic acid. The matter discussed is important in the determination of sulfur dioxide and hydrogen sulfide in gases that have been absorbed by potassium or sodium hydroxide and where most of the excess alkali has been consumed.

Determination of Sludge in Used or Oxidized Motor Oils, C. G. LUDEMAN, *Ind. & Eng. Chem., Anal. Ed.* **12** (1940) pp. 520-5.

Motor oil sludge components and asphalt components are considered to be formed through oxidation of hydrocarbons in the order of the series: slightly altered hydrocarbons, resins, asphaltenes, carbenes, and carboids. The nature and solubility of these materials are briefly discussed. A standard procedure for sludge precipitation that gives reproducible results is outlined. Three solvents, isopentane, carbon tetrachloride, and carbon disulfide, are recommended. These precipitate asphaltenes, carbenes, and carboids, respectively. These solvents comply with A.S.T.M. definitions and general usage in this field of work. The solvent or sludge precipitant employed greatly affects the amount of sludge obtained from an oxidized or used motor oil. Of the solvents investigated, the greatest amount of sludge is precipitated by isopentane. The amount of sludge precipitated is little affected by the time of standing after dilution. Temperature has an appreciable effect on the precipitation of sludge, the amount precipitated being inversely proportional to the temperature over the range investigated. The amount of sludge precipitated increases with increasing dilution, a maximum being attained at 25 cc. of isopentane per gram of sample. Of the filters tested for sludge filtration, the most convenient and reproducible is a carefully prepared asbestos-filled Gooch crucible.

Detection and Determination of Ethylene Glycol in Lubricating Oil, H. LAMPREY, E. E. SOMMER, AND A. D. KIFFER, *Ind. & Eng. Chem., Anal. Ed.* **12** (1940) pp. 526-7.

The analysis of automobile crankcase oil for antifreeze materials is sometimes necessary in order to determine if leakage of engine cooling solution into the crankcase has occurred. Such analyses are important in determining whether antifreeze materials cause crankcase sludge formation as much as does water alone. A method is described for the detection of ethylene glycol in crankcase oil. This method is based on the isolation of the ethylene glycol by distillation, followed by identification by means of physical properties. The test is specific for ethylene glycol and can be made quantitative in the absence of other high-boiling antifreezes, as is usually the case.

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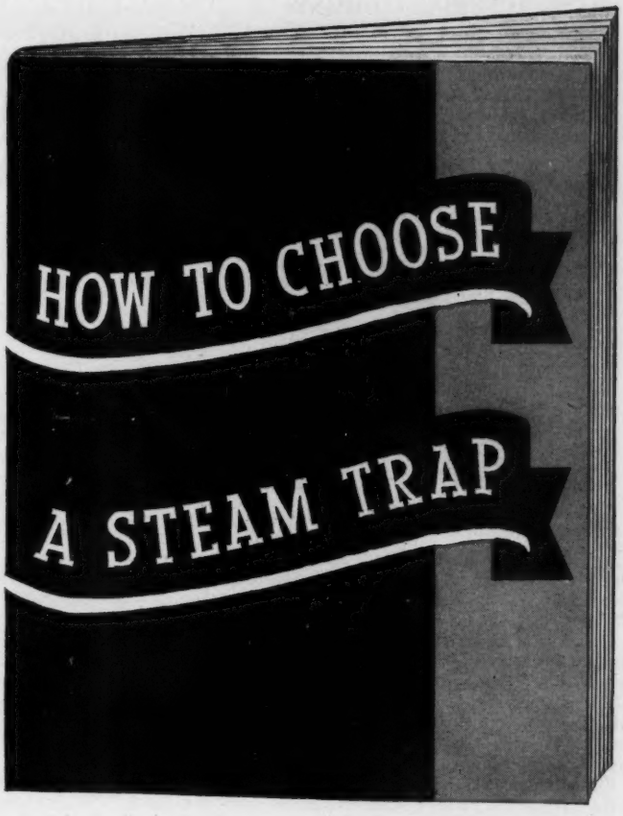

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New Equipment for the Modern Plant

Circuit Breaker

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

A small circuit breaker, designed for protection of lighting, appliance and motor circuits and combining a co-operative magnetic and thermal trip, has been announced by Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania. Designated Quicklag, it is available in ratings of 15 to 35 amperes, single pole only, 250 volts AC and 125 volts DC.

Westinghouse Quicklag Breaker

A combination of bi-metal thermal and magnetic trip actions is designed to give the device the advantage of instantaneous trip on short circuits combined with the advantage of time-delay for momentary overloads such as caused by inrush currents.

The breaker has no live parts exposed to accidental contact, calibration is permanent and sealed against tampering, contacts are low-resistant, operating mechanism gives a quick make-and-break, and arcs resulting from heavy current interruptions are snuffed out by a grid assembly. Solderless terminals are used to facilitate connections.

Automatic operation is indicated by the handle position, which has a central tripped position, and current ratings are marked on the operating handle, which is trip-free. Case is of molded Micarta.

Arc Welder

GENERAL ELECTRIC COMPANY

A new line of 500-ampere AC arc welders of a design incorporating power-factor correction to aid in eliminating lagging current has been announced by General Electric Company, Schenectady, New York.

When operated below half-load, the welder provides leading reactive kva for improvement of the shop power-factor, and when operated at no load, there is 19.5 kva available for this purpose. The power-factor correction is intended to make possible use of smaller primary cable, line switches and fuses, resulting in a saving on installation costs and permitting addition of more welders to existing feeders without causing overload.

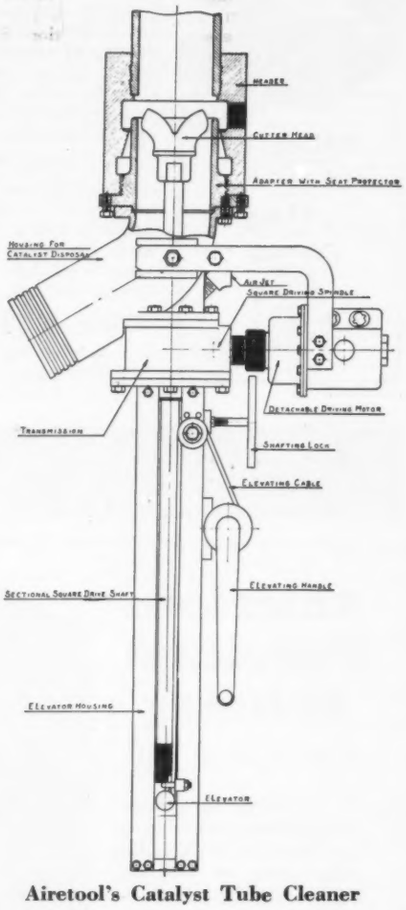
The unit features finger-tip adjustment by means of a current-changing crank, a current indicator extending up the side of the transformer case, protected output terminals accessible through holes in the insulating panel, and fan-forced ventilation to provide cool operation at high currents or high-duty cycles.

It is less than four feet high, is 21 inches in diameter and weighs 600 pounds. Maintenance is described as limited to lubrication of the fan and current-adjuster every 12 to 18 months, although the case is removable for inspection.

Catalyst Tube Cleaner

AIRETOOL MANUFACTURING COMPANY

A tube cleaner designed to eliminate hazards associated with cleaning reactor tubes in polymerization units after the effectiveness of the catalyst has been reduced, has been announced by Airetool Manufacturing Company, Springfield, Ohio.



Airetool's Catalyst Tube Cleaner

In operation, refuse is deposited in receptacles placed at the bottom of the discharge opening, forming a part of the main housing, or conducted to a disposal plant by means of an exhaust fan or conveying system.

The device eliminates hazard of dust from the surrounding atmosphere, and makes unnecessary use of protective appliances to prevent burns or other inconveniences to the operators.

Oil Filter

S. G. FRANTZ COMPANY

A filter for lube oil purification designed to magnetically extract iron particles, as fine as 1/25,000-inch in diameter, from suspension in circulating systems, has been announced by S. G. Frantz Company, 161 Grand Street, New York. It may be located in the oil pipe line to become part of the circulating lube oil system.

The device consists essentially of a stack of magnetized screens enclosed in a cylin-

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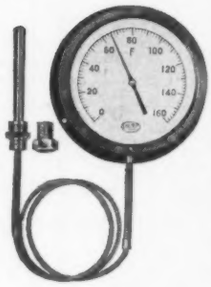

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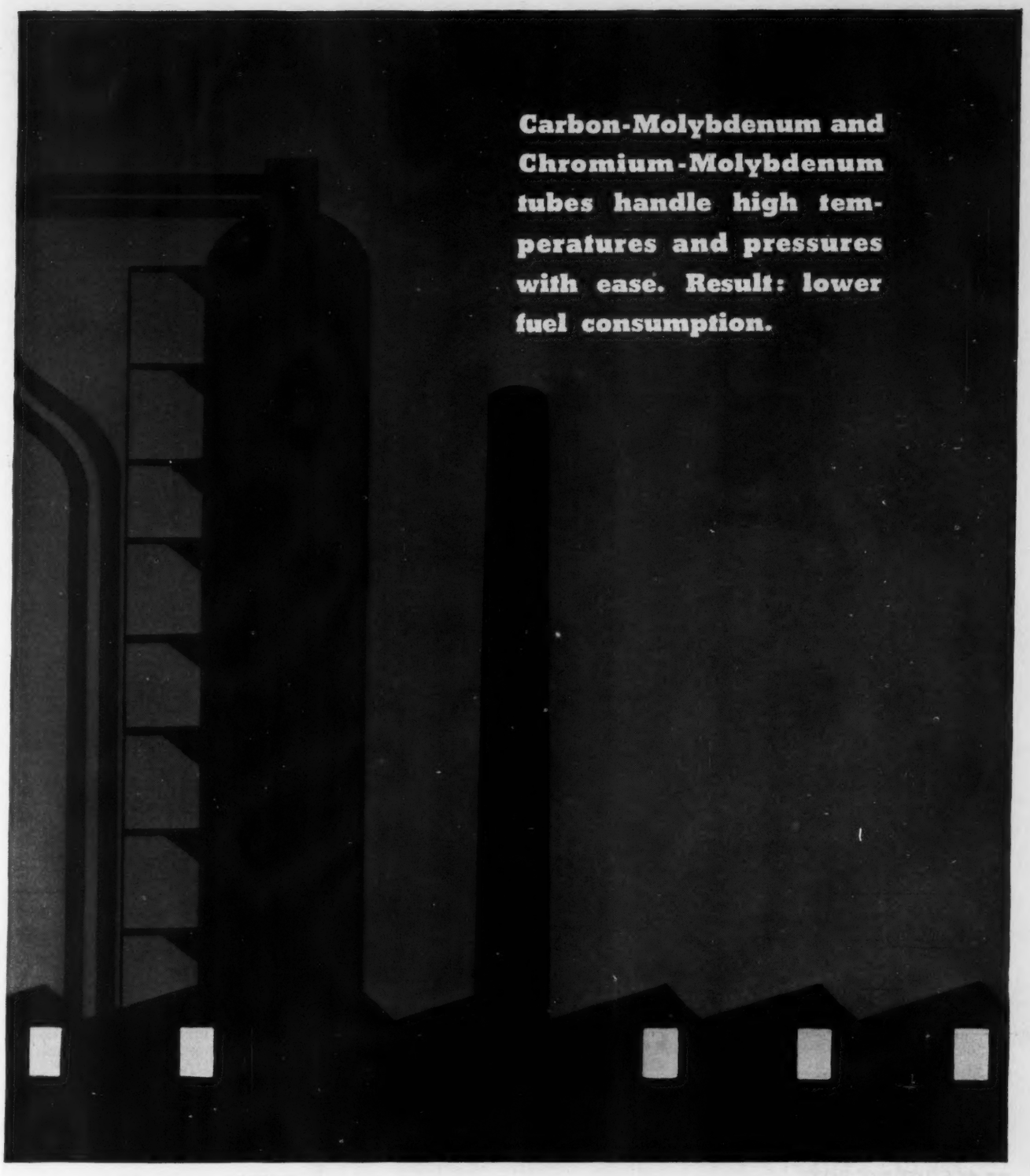

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drical casing through which the oil flows. The screens have triangular mesh openings of about ⅛-inch. Design is intended to offer very little resistance to the flow while presenting hundreds of feet of strongly magnetized edges to the oil.

Other features are lack of electrical connections or moving parts, and construction permitting quick cleaning with all parts accessible.

Offered in two models, Model P2Q has a ¾-inch pipe connection, a 10-gallon-per-minute capacity, is 5¾ inches high, 4⅜ inches long over pipe connections, has a shell diameter of 3¼ inches, and weighs 6 pounds. Model P3Q has a 1-inch pipe connection, 20-gallon per minute capacity, is 8 inches high, has a shell diameter of 4½ inches and weighs 12 pounds. Both models operate at 100 pounds working pressure.

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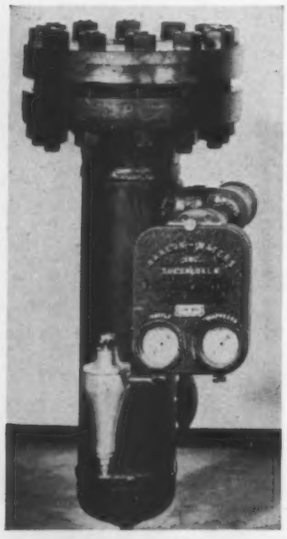

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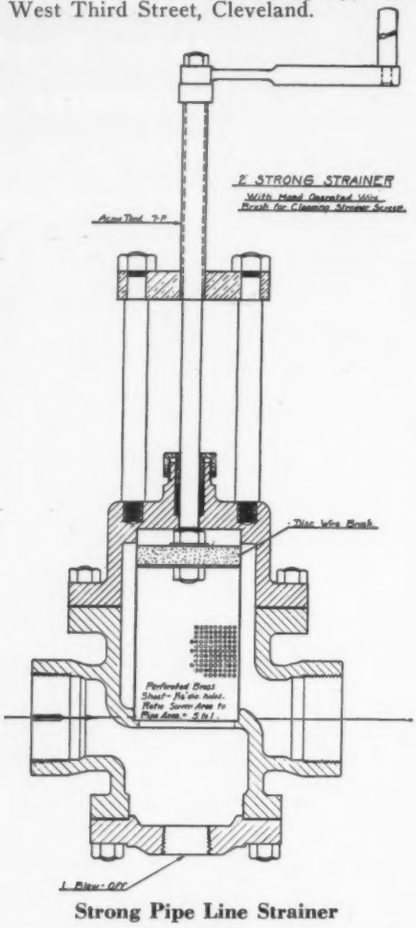
Strainer

STRONG, CARLISLE & HAMMOND COMPANY

A strainer of special construction designed for use in industrial processes where foreign matter to be removed tends to clog perforations in strainer screen, has been announced by Strong, Carlisle & Hammond Company, 1392 West Third Street, Cleveland.


2 STRONG STRAINER
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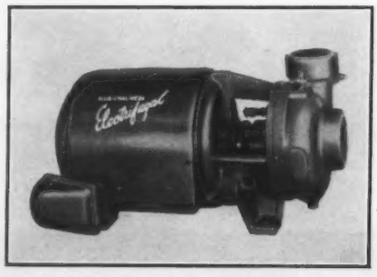
Strong Pipe Line Strainer

In operation, turning the lever handle moves a bronze wire brush up and down inside the screen, the rotation of the brush cleaning screen perforations so strainer can function. It is intended for application wherever water or steam lines contain matter adhering to screen.

Centrifugal Pump

ALLIS-CHALMERS MANUFACTURING COMPANY

A centrifugal pump that combines pump and motor unit on one shaft and one housing, designated Electrifugal pump, has been announced by Allis-Chalmers Manufacturing Company, Milwaukee.



Allis-Chalmers Electrifugal Pump

The unit has a special motor with a one-piece cast-iron motor yoke and pump bracket. The feet are cast integral with the housing and bracket, and extend under the entire unit instead of under the motor only. The motor design, with copper-bearing steel cover, meets NEMA specifications for splash-proof motors. Totally enclosed, fan-cooled motors and explosion-proof motors are also available.

In splash-proof construction, the pump is available in sizes from 1- to 10-horsepower at 3500 r.p.m., and from ¾- to 7½-horsepower at 1750 r.p.m. for heads up to 160 feet. Larger sizes are being designed.

For normal service, the pump is built with cast iron casing, bronze fitted. It can be made all iron, all bronze, all stainless steel, or of other special metals to suit a particular application.

Compressor

INGERSOLL-RAND COMPANY

A new two-stage air-cooled compressor, rated to deliver 60 feet of free air per minute at a discharge pressure of 100 pounds, has been announced by Ingersoll-Rand Company, 11 Broadway, New York.

Three models are available, all built around the same gasoline engine-compressor plant. The push-about model is mounted on roller-bearings, pneumatic-tired wheels. A turtle-back cover protects the compressor and engine from

Ingersoll-Rand Push-About Compressor

the weather and provides a means of locking the wheels against theft. The deluxe model is a spring-mounted, high-speed trailer unit with tool boxes for carrying equipment built into the sides of the body. The utility model is on a steel base for mounting directly on a service truck or built into truck body.

Electric starting is available on the utility and deluxe mountings.

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An electronic level control for both conductive and non-conductive fluids and powders, designated Type P30, has been announced by Photoswitch Incorporated, 21 Chestnut Street, Cambridge, Massachusetts.

Equipment is available to provide single-level control, on-and-off control at two levels, boiler feedwater control, and tank condensate signals. Installation entails attaching a probe fitting to the surface of the tank.

Photoswitch Level Control

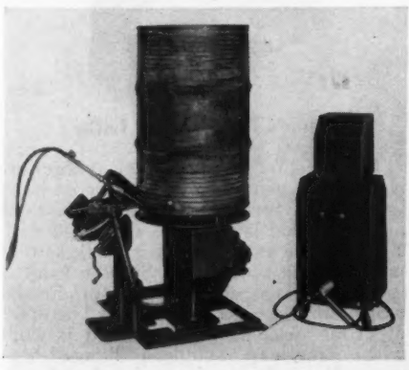
The probe circuit carries only milliamperes of current and low voltage, permitting its use with combustibles. For two-level control, probe fittings or electrodes are attached to the tank at levels representing the low point where pumping starts and the high level where pumping stops. The probes are wired to the electronic level control. When the liquid falls below the lower probe, level control closes the circuit which starts the pump, and the tank fills. When the level rises to the upper probe, the fluid acts as a conductor of the small amount of current required for operation of the level control, opening the pump control circuit.

Special tank fittings are available for use in corrosive liquids.

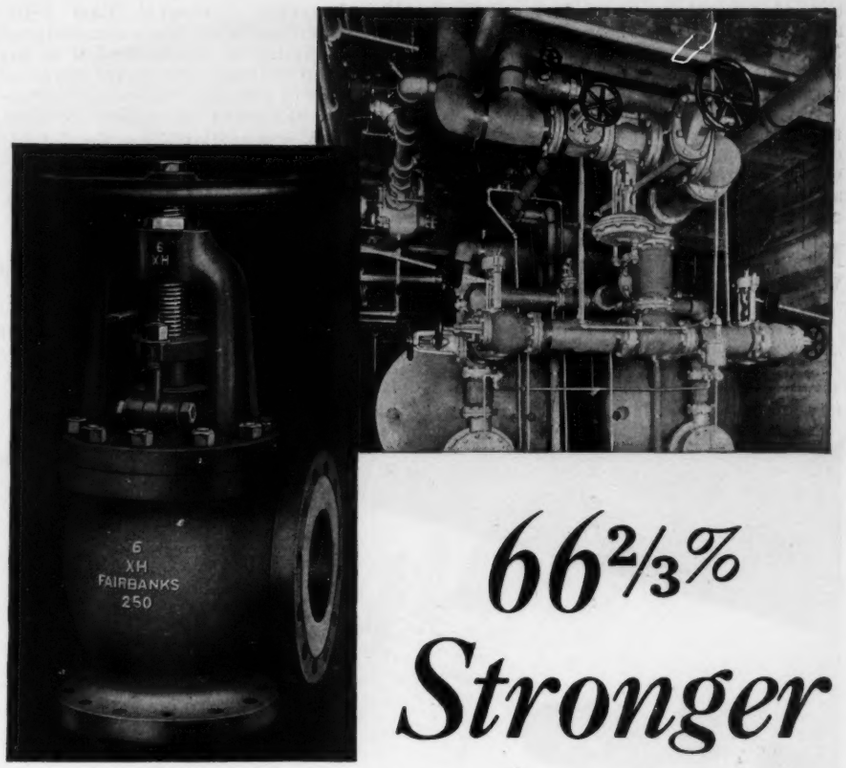
Drum Welder

McCLARY & BYERS EQUIPMENT COMPANY

A drum welding machine designed to hold the drum in an upright position and at a 30-degree angle, to revolve the drum in each position through a gear series giving high, low and neutral positions, and to provide means for varying the high and low speeds by a variable speed pulley and train of gears to allow the welder selec-



McClary & Byers Drum Welder



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tion of a revolving speed best suited to apply the weld, has been announced by McClary & Byers Equipment Company, 1009 Fruitvale Avenue, Oakland, California.

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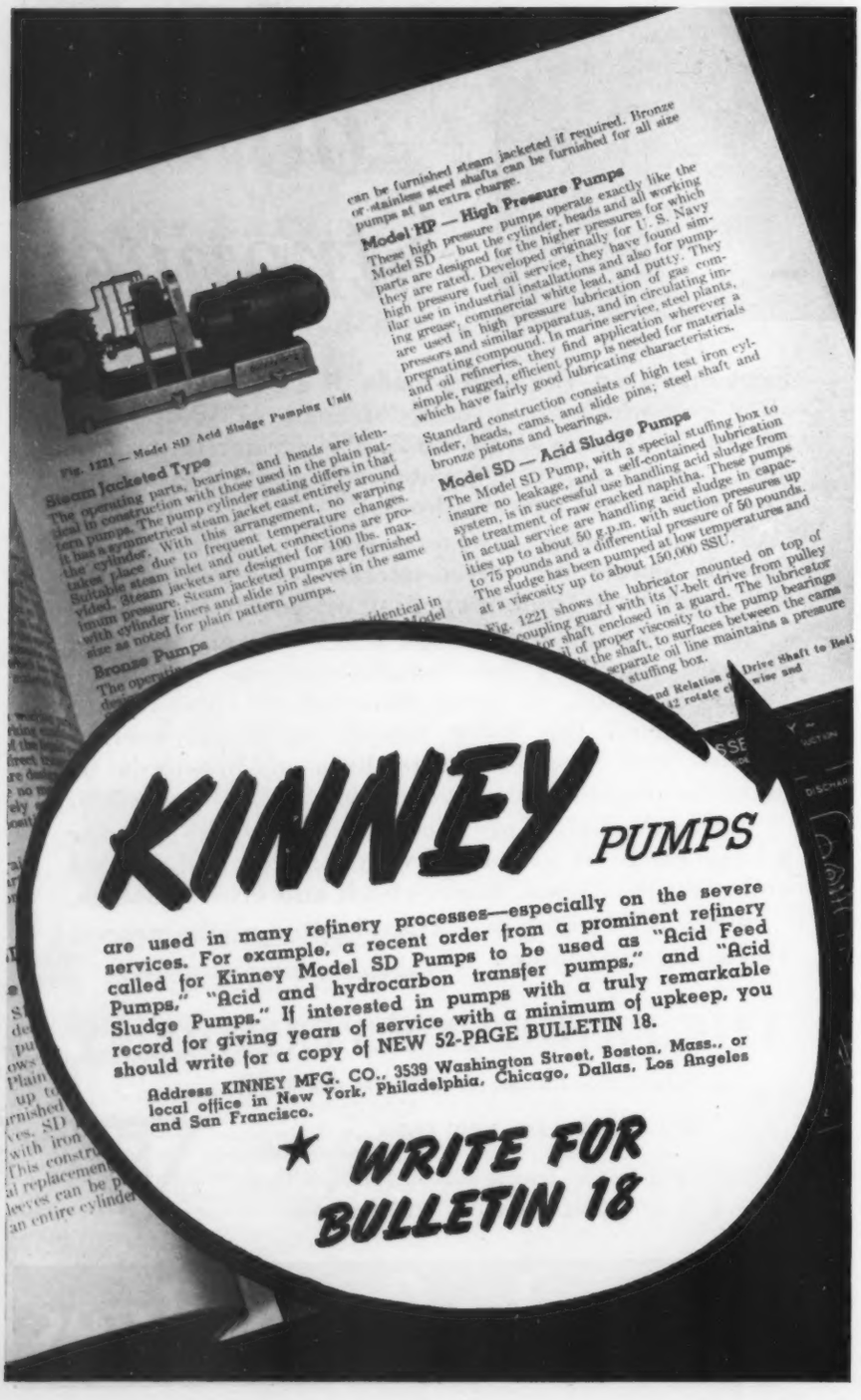
Magnetic Starter

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

A new line of across-the-line magnetic starters for use with multi-speed squirrel-cage motors of from 220 to 600 volts, 1- to 100-horsepower, has been announced by Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania. They are designed to start the motor across-the-line at any speed, and different speeds are obtained by changing the connections to the motor so as to change its number of poles.

Starters are available for the following types of multi-speed motors in 2-, 3- or 4-speed types: constant horsepower, constant torque, variable torque, single-winding motors and double-winding motors.

Features include push-button speed selection, over-load protection, low-voltage protection, de-ion arc quenchers and front-of-board wiring with accessible terminals. Optional operational features include selective speed control, compelled slow-speed start, automatic sequence acceleration and deceleration.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Current Regulator

WAGNER ELECTRIC CORPORATION

A constant-current regulator, designated Type Y-H and comprising a regulator and controller-protector switch, has been announced by Wagner Electric Corporation, 6400 Plymouth Avenue, St. Louis.

The regulator has no moving coils, but is designed to operate from no load to full load, and to immediately adjust its output voltage to varying load conditions without surges on the line or lamp circuit. It is intended for applications requiring constant current at all loads.

Intermitter

FISHER GOVERNOR COMPANY

A new intermitter for time-cycle control has been announced by Fisher Governor Company, Marshalltown, Iowa.

Fisher Governor's Intermitter

The instrument features enclosed pilot and clock assembly in a weatherproof gas-tight case of high-tensile iron cast integral with the upper diaphragm casing. Length and frequency of operating intervals may be varied to meet individual requirements.

The instrument is designed for automatic stop-cocking of high gas/oil ratio wells or distillate wells, and controlling high-pressure operating mediums to production devices.

Lathe

THE OSTER MANUFACTURING COMPANY

A lathe with a capacity of 1½-inch (round) for cutting-off, boring, tapping, reaming, facing, threading and other jobs has been announced by The Oster Manufacturing Company, 2057 East 61 Place, Cleveland.

Oster's Rapiduction Lathe

The machine, designated Rapiduction, is designed primarily as a low-cost lathe for simple turning operations without highly skilled labor. It is equipped with a cross slide and saddle for quick setting up for three operations. Spindle head is totally enclosed, carrying the spindle and worm shaft which runs in oil. The spindle runs on ball bearings and is built with American standard flanged-type nose. It is driven by a hardened and ground, steel work and bronze worm

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gear. The worm shaft is mounted on ball bearings.

Multiple V-belts from the motor to worm shaft is the method of drive, speed changes being obtainable through quick-change sheaves giving spindle speeds from 140 to 1000 revolutions per minute. A coolant pump, mounted in the base, is driven by a V-belt from the motor.

Mounted on the carriage with Key- and T-bolts, the tool post is provided with longitudinal adjustment for the length of the carriage. A variety of chucking equipment is available, including face plate, automatic and universal, and either manual or automatic stock stop can be provided.

Power is furnished by a 2-horsepower 1800/3600 revolutions per minute, two-speed induction motor with reverse or electric-braking optional.

Booster Pump

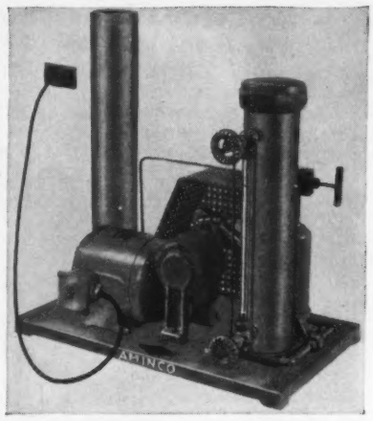
AMERICAN INSTRUMENT COMPANY

A motor-driven hydraulic pump, rated as developing pressures up to 6000 pounds per square inch, has been announced by American Instrument Company, 8010 Georgia Avenue, Silver Spring, Maryland.

The pump is designed for determining the effects of high pressures and their sudden release on various materials, for creating high test pressures for catalytic hydrogenation work, and for determining the bursting strengths of cylinders and spheres.

It consists essentially of a geared-head motor for operation on 115 or 230 volts, AC or DC, reservoir and compression chamber mounted on a cast-iron base.

Theoretical displacement per hour is 553 cubic inches; working volume of the reservoir is 1300 milliliters; actual volume of the reservoir is 3000 milliliters, and working and actual volumes of the compression chamber is 1300 milliliters, tested to 9000 pounds per square inch.



Hydraulic Booster Pump

Feedwater Treatment

AMERICAN K. A. T. CORPORATION

An emulsion of organic materials utilizing colloidal principles, designed to remove and prevent scale formations in water stills and evaporators and to replace use of acid, cracking, manual or sand-blast cleaning, has been announced by American K.A.T. Corporation, 122 East 42 Street, New York City.

The compound is designed to work with all waters and to require no chemical water analyses except to determine hardness. It does not carry over with the distillate, and scale-forming impurities are coated and precipitated as a sludge.

Mask Facepiece

MINE SAFETY APPLIANCES COMPANY

A new facepiece for its All-Service gas mask has been announced by Mine Safety Appliance Company, Braddock, Thomas & Meade Streets, Pittsburgh.

The facepiece employs non-fogging large-area lenses of laminated shatterproof glass, contoured at the sides, designed to provide maximum useful vision at all seeing angles. Dry incoming air is conducted over the lenses to prevent accumulation of moisture or fog.

M. S. A. Gas Mask Facepiece

ADJUSTS ITSELF
Automatically

Garlock CHEVRON PACKING is so constructed that it adjusts itself automatically to compensate for variations in pressure. The exclusive hinge-like, cross-sectional shape expands as the pressure increases and contracts as the pressure decreases. Friction on the rod and on the packing itself is thereby reduced to a minimum. Chevron seals tight with less wear. Genuine Chevron packing is made and sold only by Garlock.

GARLOCK 430 CHEVRON for hydraulic service; 431 for oils at low temperatures; 530 for steam, air or gas; 531 for hot oils.

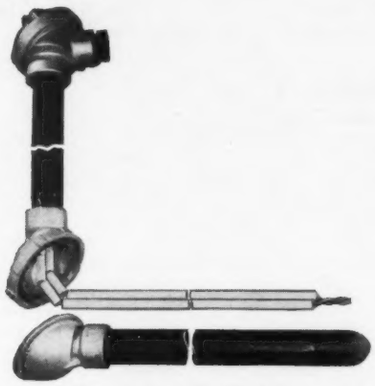
THE GARLOCK PACKING CO.
PALMYRA, NEW YORK
Tulsa, Okla. Houston, Tex. Los Angeles, Calif.

GARLOCK CHEVRON PACKING

Thermocouple Fitting

LEEDS & NORTHRUP COMPANY

A universal union for angle-type couples, designed to facilitate thermocouple replacement, has been announced by Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia.



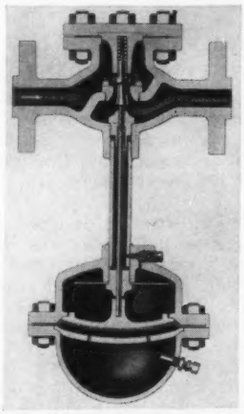
Thermocouple Fitting

The two halves of the union fit together in a ground joint to make it vapor- and fume-tight. By unscrewing a single clamping nut, which cannot fall off, the thermocouple's hot leg can be detached, or it can be rotated to any angle between 90 and 180 degrees and locked firmly in place.

Pressure Reducer

FOSTER ENGINEERING COMPANY

Two pressure-reducing regulators for steam, hot liquids and hot gases, rated for initial pressures up to 2500 pounds per square inch, delivery pressures up to 1200 pounds per square inch, and temperatures up to 1000° F., has been announced by



Foster Pressure Reducing Regulator

Foster Engineering Company, 109 Monroe Street, Newark, New Jersey. Type 39-Q1 is single-seated, and Type 39-Q2 is double-seated.

The regulators employ no operating springs or stuffing box, obtaining loading by air to insure constant regulation. A constant air load in the dome is designed to provide accurate and sensitive regulation. Single-seated styles are provided for dead-end service, shutting in direction of flow for tight closure, and double-seated models are offered for continuous-flow services. Parts are readily accessible, and renewable without removing body from line. Through-bolted construction of diaphragm chamber simplifies inspection, and no special tools are required.

Pressure regulated by the valve can be adjusted at a distant control point located by installation of an extension loading tubing for hand pumping, or by a pilot control valve where air supply is available.

Safety Shoes

LEHIGH SAFETY SHOE COMPANY

Manufacture of its line of Par-Grip safety shoes with a neoprene-treated vamp and special-compound neoprene sole designed to give skid-protection, toe protection and long service where floors are oily, greasy or wet with strong cleaning compounds, has been announced by Lehigh Safety Shoe Company, Allentown, Pennsylvania.

The sole is made in one flat piece from toe to heel, the construction being designed to double the normal traction area. The sole is moulded in a deep-diamond-shaped grid pattern forming suction cups to grip wet floors like a rubber plunger. It is intended for both indoor and outdoor wear.

The safety sole is available in knee-boot or ankle-boot models, black or white, and with a steel toe box built in for toe protection. The shoes have a leather insole to prevent irritation commonly caused by all-day use of rubber footwear.

Galvanometer

GENERAL ELECTRIC COMPANY

A new galvanometer, designed for applications where wall types were heretofore frequently necessary, such as temporary setups for factory and laboratory testing; permanent installations

PERMANENT FURNACE LINING
EASY TO INSTALL
YOUR ANNUAL FURNACE COSTS may be reduced by this simple, easy to install, Thinsulite wall and arch construction applied to any heater and to most parts of boilers.
Thinsulite consists of 3" or 4½" standard refractory tile supported by heat-resistant castings and backed up with ample insulation. It is a low first cost, permanent, sectionally supported construction.
A saving in labor in addition to the saving in materials helps to reduce the initial cost, and the permanently air-tight and heat-tight construction saves operating costs and shutdowns.
Now you can have the efficiency of an 18" wall in a 6" (overall) Thinsulite wall at a saving in annual costs. Be sure to see the heat transfer curves in the new Thinsulite catalog, sent on request.
Thinsulite
WALLS and ARCHES
M. H. DETRICK COMPANY
140 S. DEARBORN ST. CHICAGO, ILLINOIS

for testing instruments, material and apparatus for production where rapid readings and minimum fatigue to the operator are essential, and for apparatus requiring an external galvanometer, has been announced by General Electric Company, Schenectady, New York.

Sensitivity of the instrument is obtained largely by an arrangement of two fixed mirrors mounted inside the case, one on each end, to increase the effective light beam length.

The galvanometer element and optical system are mounted in a case of cast-aluminum alloy. The scale, of translucent compound, is double-marked 50-0-50 and 0-100 in 1-mm divisions. The light source is provided by an automobile-type lamp. An external adjuster is provided for setting the element on zero. Alnico magnets are employed and the coils are of Formex wire.

DC Motors

GENERAL ELECTRIC COMPANY

A new line of DC motors featuring rolled-steel frame and improvements in end-shield and bearing-bracket designed to give protection from external damage, have been announced by General Electric Company, Schenectady, New York. They employ Formex wire coils and the Glyptal insulating varnish to provide resistance to impact, abrasion and the action of foreign materials.

Furnished with sleeve or ball bearings, the motors are available in constant-speed ratings from ½-horsepower at 850 revolutions per minute up to and including 60-horsepower at 1750 revolutions per minute, and in adjustable-speed ratings from ½-horsepower at 850/3400 revolutions up to and including 15-horsepower at 500/1800 revolutions.

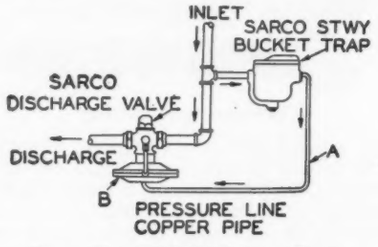
Motors in larger ratings, beginning at 50-horsepower, 850 revolutions per minute, employ a new system of self-ventilation, extra protection of all current-carrying and rotating parts, and large conduit boxes. New V-type double brush-holders are designed to give better commutation and to permit rotation in either direction. A new lifting lug is provided to facilitate handling.

Steam Trap

SARCO COMPANY

An indirect steam trap of large capacity and designed for pressures up to 175 pounds, designated Type BSDE, has been announced by Sarco Company, 183 Madison Avenue, New York.

The device consists of a standard inverted-bucket steam trap of small size



Sarco Type BSDE Steam Trap

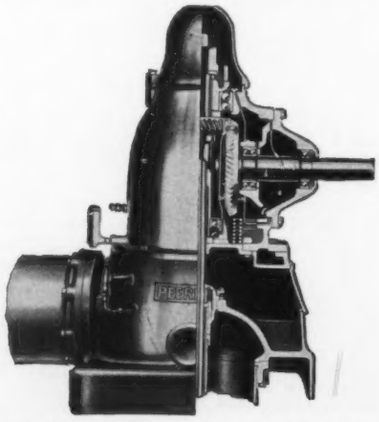
coupled to a special diaphragm valve in the condensate-discharge line. The valve is normally closed. When condensate opens the discharge valve of the pilot trap, pressures reaches the large diaphragm of the main valve and opens it. It is held open as long as condensate flows, but shuts as soon as the trap closes.

Turbine Pumps

PEERLESS PUMP COMPANY

Improvements in its line of deep-well turbine pumps, including a change in bearing application in design of geared heads, have been announced by Peerless Pump Company, 301 West Avenue 26, Los Angeles.

The take-off shaft is designed to carry increased loads, and double-row ball bearings support the horizontal and vertical shafts and are placed adjacent to the spiral bevel gears. A heavy-duty thrust bearing supports the lower end of the geared shaft sleeve, while an additional thrust bearing supports the outer end of the horizontal drive shaft. The four bearings are lubricated by an oil-pressure system that cir-



Peerless Improved Pump Head

with **AIRETOOL'S**
NEW "3000" SERIES TUBE CLEANERS

The additional power developed by the new "3000" Series Airetool Tube Cleaners means quicker cleaning jobs. A wider range of cutter head combinations can be used in overcoming severe coke formations. In one actual case, cleaning time was cut well over 50%. That type of performance means worth-while savings in time and money.

Other features of Airetool's "3000" Series are: no dead centers . . . motor picks up instantly . . . constant torque at low speeds prevents stalling.

There is an Airetool Tube Cleaner for every type tube. Our Bulletin NR-58 describes many of these cleaners and other refinery specialties. Write for it today.

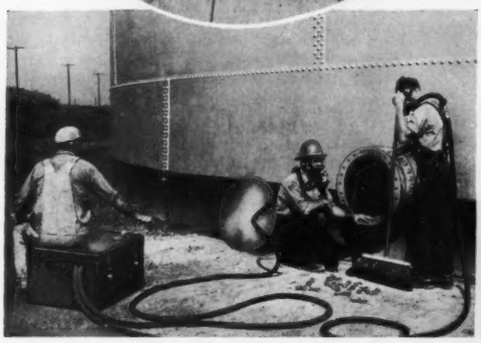
A new Catalyst Reactor Tube Cleaner eliminates the dangers of this tube cleaning job. Details on request.

AIRETOOL
MANUFACTURING COMPANY
SPRINGFIELD, OHIO

***Representatives in Principal Cities*—New York Address: 50 Church St.**

EXTRA *wide vision* EXTRA *comfort*

WITH DEPENDABLE SAFETY AND CONVENIENCE!



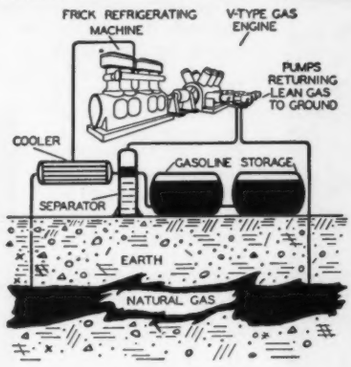
The M.S.A. *Combination* HOSE MASK
WITH NEW *All-Vision* FACEPIECE

(United States Bureau of Mines Approved)

The time-proved superior features of the M.S.A. Combination Hose Mask have established this product as "standard equipment" in refinery service—employed wherever top quality in hose masks is demanded. Now, with the new M.S.A. All-Vision Facepiece, **even greater** wearing ease has been supplied! Maximum useful wide-angled vision, through scientifically-contoured lenses of large area, is protected by built-in fogproof construction. Dead air space in the facepiece has been sharply reduced, and the facepiece itself, of molded flexible rubber, is lighter in weight and easily fits any type face with a perfect gas-tight seal, without binding, uncomfortable tension or pressure. Replaceable lenses, quick-adjusting headstrap swivel buckles are further refinements—but **let us give you the complete details—write today!**

DEMONSTRATIONS GLADLY ARRANGED ON REQUEST

MINE SAFETY APPLIANCES COMPANY
Braddock, Thomas & Meade Sts. · Pittsburgh, Pa.
District Representatives in Principal Cities



Gasoline now made from natural gas with

Tide Water Associated-Seaboard Oil are doing it at the rate of 38,000 gallons a day in their new plant near Palestine, Texas, using the Vaughan recycling process shown in the sketch.

Two big Frick 4-cylinder compound compressors, of unique design, condense the high-octane gasoline by cooling 40 millions cubic feet of natural gas, daily, to temperatures near zero.

Look to Frick Engineers (they're in Branches and with Distributors all over the world) when you want dependable, profit-making equipment for air conditioning, ice-making, or any other cooling service.

FRICK CO., WAYNESBORO, PENNA.

TRADE FRICK MARK

Refrigeration

culates cooled oil to both bearings and gears. An oil seal is placed on the end of the bearing housing to prevent leakage of oil from the outer bearing on the take-off shaft. The seal is equipped with an annular garter spring and the treated leather element is oil-resistant.

Annealed semi-steel castings are employed to insure against distortion and misalignment of gears and other moving parts. Head assembly is streamlined, and gearing is completely housed. Gears are heat-treated, hardened and ground nickel alloy and lapped for specific operating tooth capacities.

Standardized speed ratios of 1 to 1, 1⅓ to 1, 1½ to 1 and 2 to 1 are provided. The head provides for connection with universal shaft to gas engines, steam engines or any other power unit.

BUSINESS NOTES

Hewitt Rubber Completes New Factory Building

Hewitt Rubber Corporation, Buffalo, New York, recently celebrated open house on completion of a plant-wide expansion and improvement program.

Formal dedication was made by Thomas Robins, Jr., company president, with unveiling of a bronze plaque on the second floor designating the name of the new building as the Twombly Building, honoring Earle K. Twombly, vice president in charge of manufacturing.

The building is three stories and of brick fire-proof construction. Glass brick windows are used on three sides, so designed that light is reflected to the ceilings, while conventional steel casement windows are used on the fourth wall to provide ventilation. Interior walls are of glazed tile.

Wyatt Metal & Boiler Works Expands Houston Plant

Wyatt Metal & Boiler Works has recently completed an expansion program at Houston, including a 50 percent enlargement of the office building, a new building for use of inspectors and storage of records, a new fabricating plant for light work, installation of a new 5-ton crane, and a new storage yard equipped with a locomotive crane.

Production thus far in 1940 has far exceeded that of any previous period in the company's history.

Moore Named Southwestern Representative for McKee

Arthur G. McKee & Company, Cleveland, has announced appointment of Chester E. Moore as Southwestern sales representative with headquarters at the company's new sales office in the Commerce Building, Houston.

Moore has been associated with the company for many years, both in an engineering and a sales capacity, and for the past ten years has been the company's European sales representative with headquarters at London, England.

Spraragen, French, Armstrong Honored by Welding Group

The American Welding Society, holding its annual meeting in Cleveland last month, honored three men for outstanding work in the welding field.

The Samuel Wylie Miller Memorial Medal was presented to William Spraragen, technical secretary of the society, for conspicuous contributions to the art and science of welding during 21 years in the field.

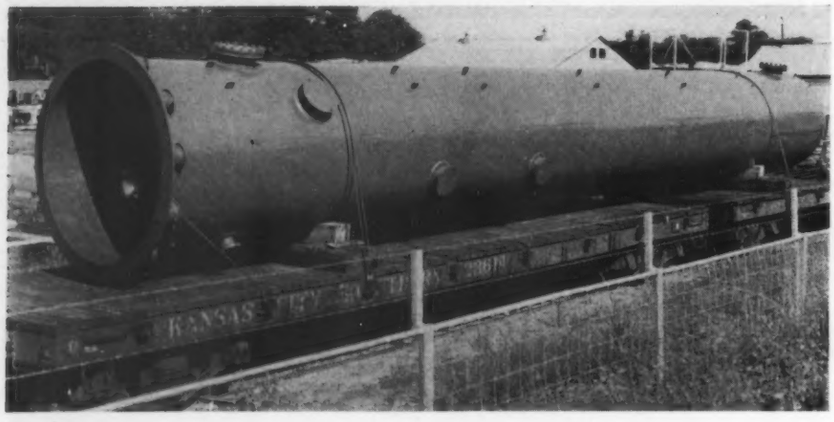
W. Spraragen

The Lincoln Gold Medal was presented to H. J. French and T. N. Armstrong, Jr., metallurgists with The International Nickel Company, for a paper judged the most important contribution to the development of welding. It was on "Weld Hardening of Carbon and of Alloy Steel," and was presented at the society's annual meeting in Chicago last year.

H. J. French

T. N. Armstrong

MADE BY BEAIRD



To have it "Made by Beaird" is your safest assurance when purchasing a pressure vessel. The facilities of Beaird's 10-acre plant include the entire cycle of manufacturing, from Engineering and Design to completed Fabrication of Pressure Vessels to A.S.M.E. and A.P.I.-A.S.M.E. Codes. Tanks and Structural Steel for every refinery need.

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